SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

1953 Literature Review, Part I—Research Committee

Metropolitan Fringe Area Sewerage—Klegerman

Outfall Studies—Bullen and O'Connor

Paper Mill Waste Reduction—Drummond

1953 Industrial Wastes Forum

MAY, 1954—VOL. 26, No. 5

Make Plans to Attend

27TH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

NETHERLAND PLAZA HOTEL
CINCINNATI, OHIO

October 11-14, 1954

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS
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ACCELERATED SLUDGE DIGESTION NOW A FACT

at the Columbus, Ohio Sewage Treatment Works

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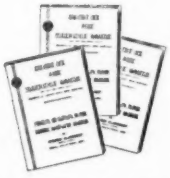
*The only proven Process for accelerating biological digestion. (Pat. app. for.)



Reprints of the paper by Professor P. F. Morgan on the development of this Process, and a paper by Mr. James H. Bladgett on the Columbus installation are available on request.

The Catalytic Reduction Process is offered through the Catalytic Reduction Co., Inc., a subsidiary of the Chicago Pump Company.

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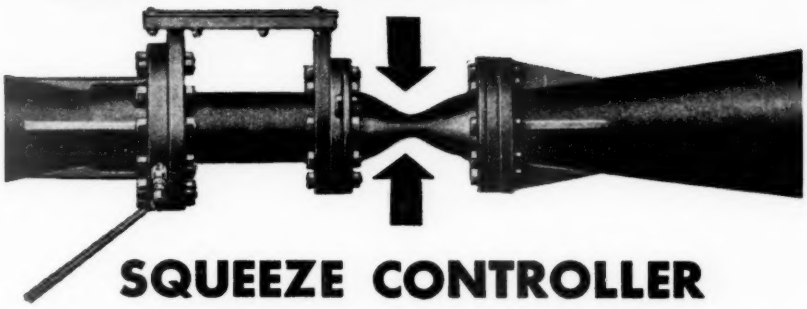

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Association	*Place*	*Time*
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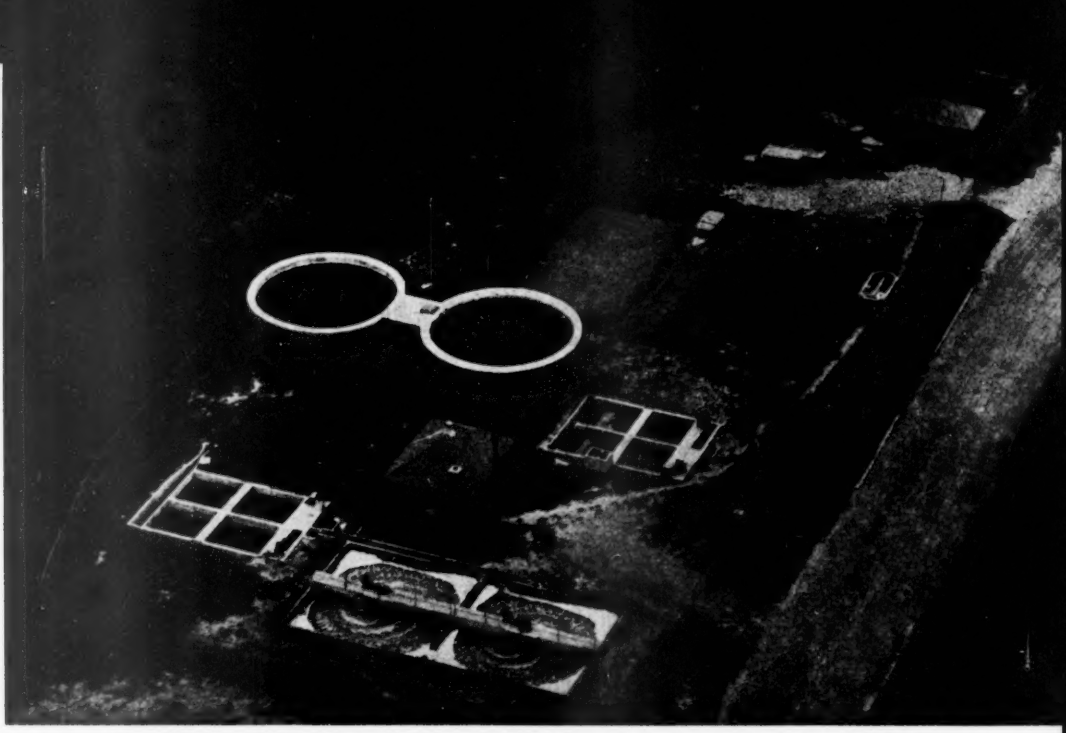
Michigan Sewage and Industrial Wastes Assn.	Kellogg Center, Michigan State College, East Lansing, Mich.	May 22–24, 1954
Alabama Water and Sewage Assn.	Pitts Hotel and Alumni Dorm, Auburn, Ala.	June 7–9, 1954
New York Sewage and Industrial Wastes Assn.	Hotel Syracuse, Syracuse, N. Y.	June 14–15, 1954
Institute of Sewage Purification	Jubilee Theatre, Coronation Street, Blackpool, Eng.	June 22–25, 1954
Central States Sewage and Industrial Wastes Assn.	Hotel Leland, Richmond, Ind.	June 24–26, 1954
Pennsylvania Sewage and Industrial Wastes Assn.	The Pennsylvania State College, State College, Pa.	Aug. 25–27, 1954
Iowa Sewage Works Assn.	Hotel Russell-Lampson, Waterloo, Iowa	Sept. 14–16, 1954
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Andrew Jackson Hotel, Nashville, Tenn.	Sept. 20–22, 1954
North Dakota Water and Sewage Works Conf.	Hotel Dakota, Grand Forks, N. D.	Sept. 22–24, 1954
Georgia Water and Sewage Assn.	Georgia Institute of Technology, Atlanta, Ga.	Sept. 22–24, 1954
Missouri Water and Sewage Conf.	Hotel Governor Jefferson City, Mo.	Sept. 26–28, 1954
South Dakota Water and Sewage Works Conf.	Lawler Hotel Mitchell, So. Dak.	Sept. 28–30, 1954

TWENTY-SEVENTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
Ohio Sewage and Industrial Wastes Treatment Conference
Netherland Plaza Hotel, Cincinnati, Ohio
October 11–14, 1954

Pacific Northwest Sewage and Industrial Wastes Assn.	Hotel Eugene Eugene, Oregon	Oct. 21–23, 1954
Canadian Institute on Sewage and Sanitation	Windsor Hotel Montreal, P. Q. Can.	Oct. 25–27, 1954
New England Sewage and Industrial Wastes Assn.	Hotel Stratfield, Bridgeport, Conn.	Oct. 28, 1954



Recently expanded sewage treatment system at Webster-Crestwood, St. Louis County, Missouri, suburban development

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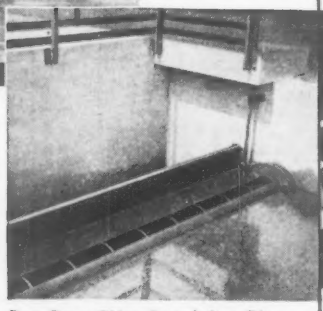

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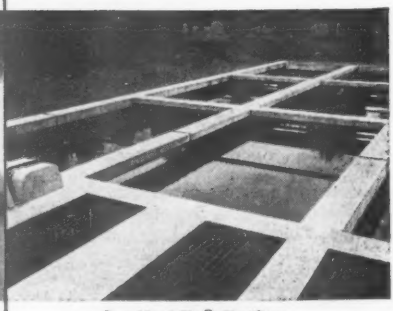

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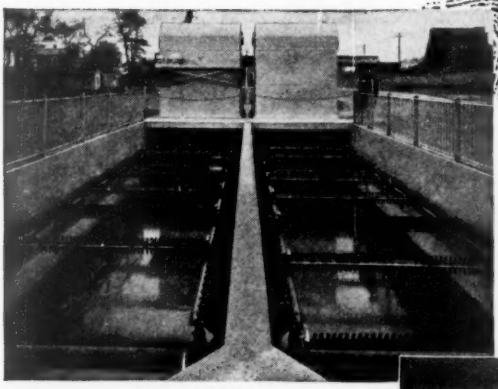

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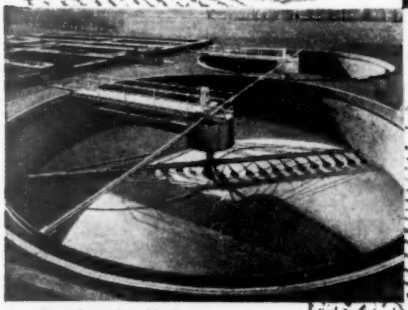

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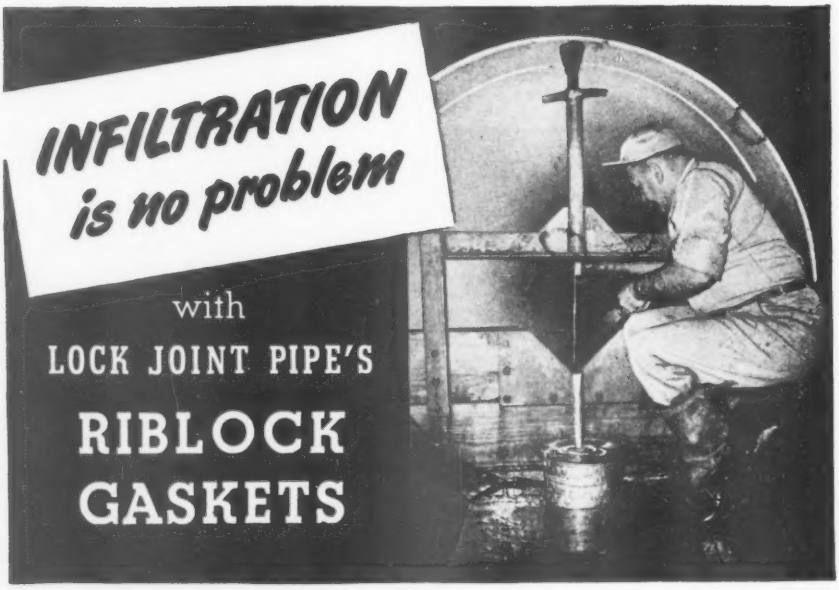

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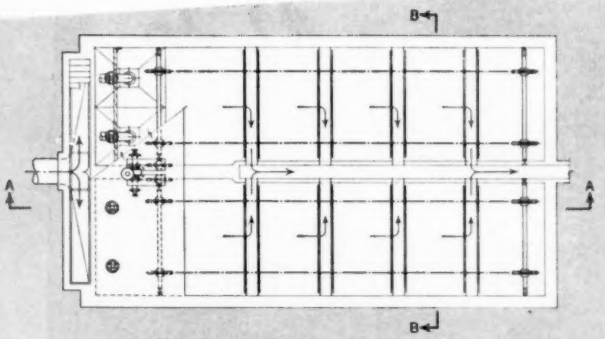
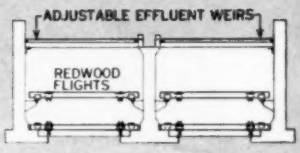
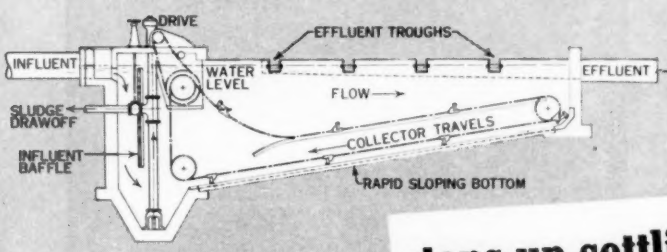
New UNIFLOW settling tank







Link-Belt's new UNIFLOW settling tank can be utilized for economical removal of solids from water, sewage or industrial liquids. Uniflow tanks are equipped with Link-Belt Straight-line Sludge Collectors which will remove sludge from the tank floor and scum from the surface.

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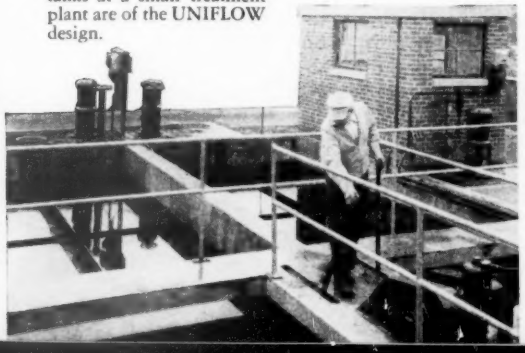

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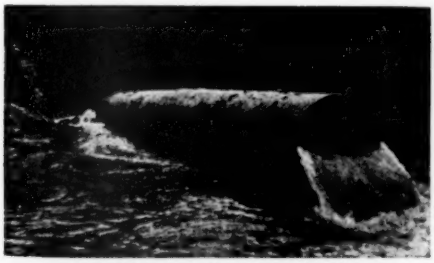
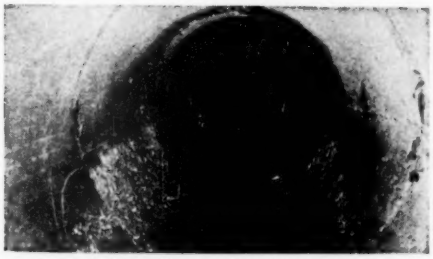


Threading cracked sewer in Georgia



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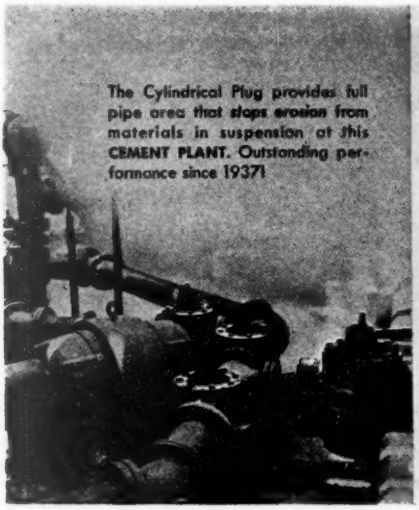
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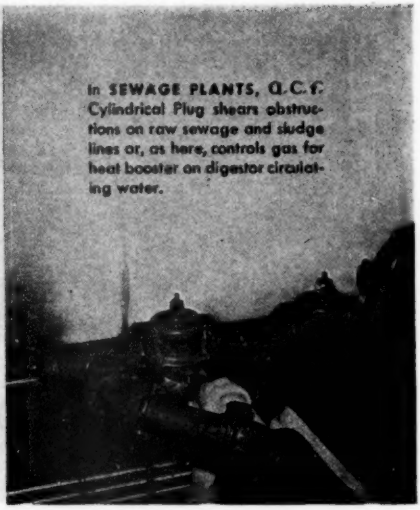
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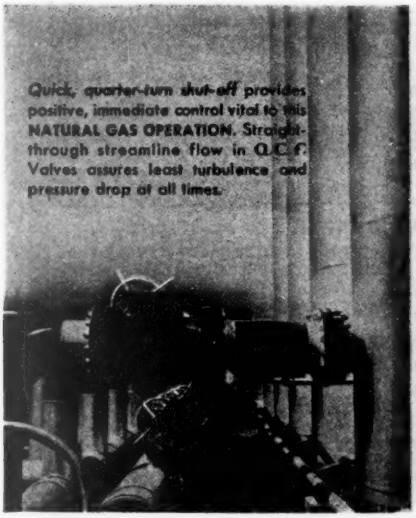
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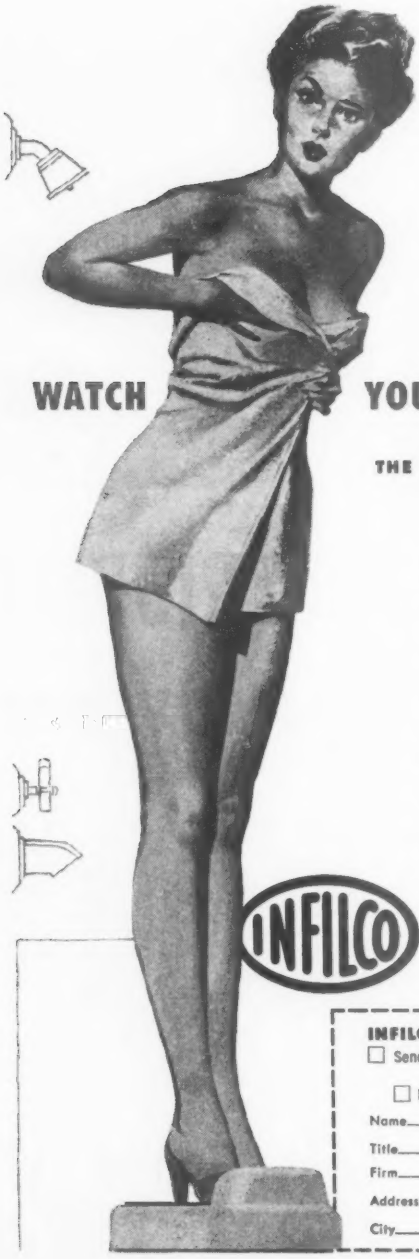

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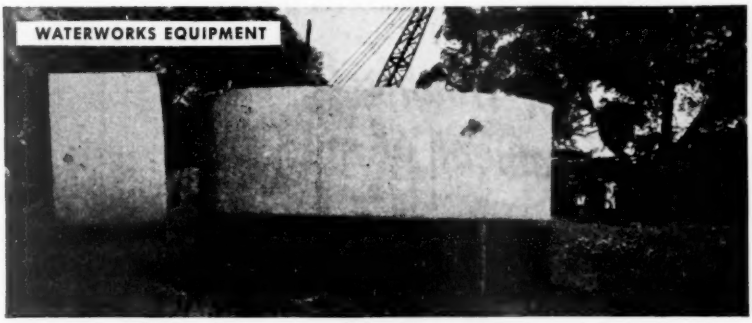

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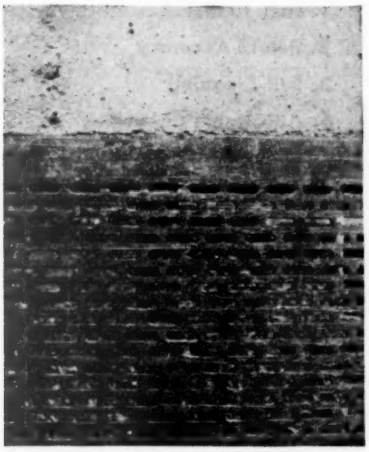

Made of ¼-inch-thick Everdur plate, circular screens are 18 inches high, having ¼-inch oblong perforations. Total open area is about 37%.

Caisson Wells, Inc., of New York City, did the job. Jordan S. Asketh of this company conducted the exploratory work. Wallace M. Graves, Consulting Engineer, Bound Brook, N. J., was in charge. Edward Purzicki was Waterworks Superintendent.

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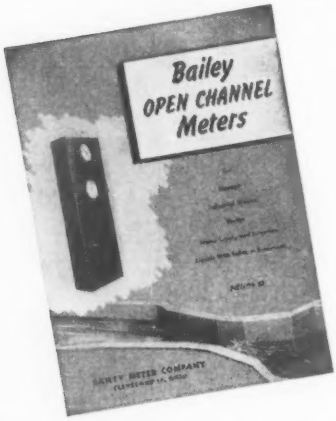

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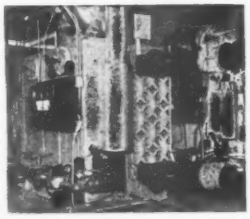

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 26 **May, 1954** **Number 5**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
Herbert P. Orland, *Associate Editor* Dr. F. W. Mohlman, *Advisory Editor*
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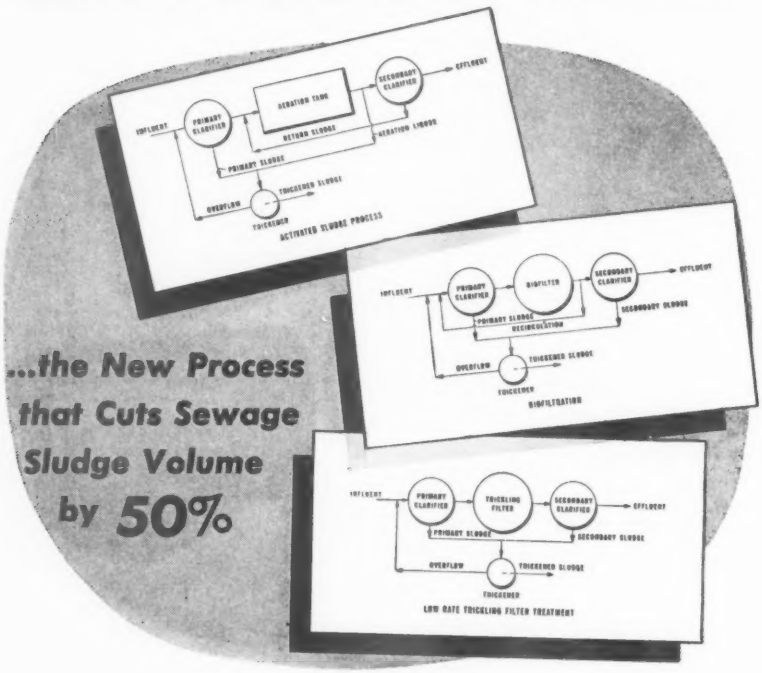

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1953 Literature Review

A CRITICAL REVIEW OF THE LITERATURE OF 1953 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

By H. Heukelekian, *Chairman*, D. E. Bloodgood, G. P. Edwards, M. B. Ettinger, R. D. Hoak, R. S. Ingols, P. W. Kabler, M. Katz, R. R. Kountz, V. W. Langworthy, R. Manganelli, P. H. McGauhey, W. A. Moggio, W. A. Moore, H. E. Orford, R. C. Palange, G. A. Rohlich, C. C. Ruchhoft, N. H. Sanborn, L. R. Setter, D. B. Smith, H. A. Trebler, and L. W. Van Kleeck

Committee on Research, Section A, Federation of Sewage and Industrial Wastes Associations

This first of two sections of the review deals with analytical methods, sewage, and radioactivity. The second section, dealing with industrial wastes and water pollution, will be published in the June 1954 issue of This Journal.

ANALYTICAL METHODS

Biochemical Oxygen Demand

Orford *et al.* (46), in a study of the B.O.D. of wastes, made use of a single dilution technique. The method consisted of incubating a dilution of the waste in two 1-gal. jugs. All necessary analyses were made from samples drawn from one jug, which was kept full and stoppered continuously. The sample volumes withdrawn from this jug were replaced from the second jug, thus preventing reaeration. When the D.O. of the two jugs approached depletion, their contents were reaerated and sampling continued. The authors claim for this method of B.O.D. measurement the following advantages:

1. All B.O.D. determination are made on one dilution only.
2. Sample volume is sufficient for all necessary analyses.
3. Less erratic B.O.D. curves are obtained.
4. The procedure requires less incubator space.

Viehl (57) made a study of the B.O.D. determination using the ordinary dilution technique and using dilutions in which the dissolved oxygen concentration had been increased by means of gaseous oxygen. The author points out that the usefulness of the former method is more limited, since with strong wastes the dilution factor is high. With the increased oxygen concentration method proposed, the initial D.O. was between 30 and 35 p.p.m. and higher concentrations of the waste were used. The residual D.O. was determined at intervals over a 48-hr. period. It is claimed that by increasing the D.O. above 10 p.p.m. nitrification is inhibited.

Akerlindh (1) suggested that when seeded dilution water and low concentrations of samples are used, the B.O.D. of a waste should be determined from at least two different dilutions giving suitable depletions of oxygen. The incubation of the blank may be eliminated. The B.O.D. of the waste is then calculated by an equation which takes into account the dilution factors and the depletions of the two dilutions. The B.O.D. of the diluting factor can also be calculated from the same data by another equation.

Rapid methods of analysis of packinghouse wastes to replace the B.O.D. determination for a reliable check for nitrogen and grease losses from the plant and the probable effect on the receiving stream were investigated by Hirlinger and Gross (25). Three chemical methods were compared on a number of samples; namely, oxygen consumed by iodic acid method, reflux chromate method, and by calculation from nitrogen and grease analyses. Each method gives data sufficiently accurate for the stated purposes.

Coin *et al.* (13) studied the relationship between the B.O.D. and the initial oxidation reduction potential of the sample. It was found that if the redox potential was approximately + 0.295 v., the best results could be obtained by using a 1:20 dilution of the sample.

Oxygen Consumed

Roberts and Sanderson (49) presented a discussion of various oxygen consumed methods and reached the conclusion that the Moore dichromate procedure gave the most reproducible results. With various types of industrial waste they showed that the use of silver sulfate as a catalyst yielded higher oxygen consumed values in all cases. They point out, however, that the method is not applicable to samples with a low oxygen consumed value. Willaux (60) used a modification of the permanganate method of Kubel and Tieman in determining the oxygen consumed values of waters relatively unpolluted and highly polluted. It was found that the amount of oxygen consumed from permanganate increases with increase in contact time when a large excess of $KMnO_4$ is present. They recommended that the amount of permanganate added should exceed by 50 per cent the exact amount required and that boiling be continued for 10 min. before the addition of the oxalic acid. Niedercorn *et al.* (43) used an alkaline-permanganate method in determining the oxygen consuming value of industrial wastes. They claim that it is not subject to interference from high chloride concentration, that the method is rapid (10 min.) and that the values obtained approximate 60 per cent of the 5-day B.O.D. Hydrocarbon chains are resistant to oxidation by this method.

Due to the fact that periodate has the property of oxidizing certain organic bonds, especially those present in the organic compounds found in pea cannery wastes, Flay (15) used this method for evaluating such wastes. He obtained an excellent correlation between the 5-day B.O.D. and the oxygen consumed from periodate. Ivekovic and Gertner (29) studied the oxygen consumed values obtained by the permanganate method using contact periods of 15, 30, 45, and 60 min. Various types of organic compounds were used. The relationship (30-min. O.C./15-min. O.C.) is called the "relation of oxidizibility" or (R_o). The more readily the organic matter present is oxidized the nearer R_o approaches 1, indicating more recent pollution. They also used NaOCl as an oxidant and found that for compounds rich in nitrogen the ratio of O.C. from NaOCl/O.C. from $KMnO_4$ was high, indicating recent fecal pollution. Using 1 to 2 N $Ce(SO_4)_2$ and back titration with $FeSO_4$, Kimoto (32) studied the oxidation of a wide variety of organic compounds, including alcohols, phenols, amines, amino acids, and high molec-

ular weight compounds. The original article gives the titration conditions for each compound, the limits of accuracy obtained, and the probable mechanism of the oxidation.

A number of papers were published during the year in which procedures are described for the oxidation of particular organic compounds. These methods could be used in the oxidation of compounds other than those for which they were specifically set up. These papers include those of Schulz (50) (oxidation of starch and laurylamine acetate), Launer and Tomimatsu (36, 37) (oxidation of carbohydrates, cellulose, and aromatic compounds), Cardone and Compton (10) (oxidation of diethylene glycol), and Reznikov and Farber (48) (oxidation of glycerol).

Dissolved Oxygen

Harper (20) described a semi-micro method for the determination of dissolved oxygen in sea water. He used the regular Winkler reagents and approximately a 20-ml. sample of the water. The actual volumes of the sample containers were previously determined by weighing. The titration of the liberated iodine was made by using a 2-ml. pipette fitted with a 3-way stopcock. The D.O. results obtained checked quite closely with those obtained by the macro method.

Wickert and Ipach (59) claim that by using the bromine-difference method the dissolved oxygen could be determined in the presence of reducing compounds such as Na_2SO_3 and $Na_2S_2O_4$. They oxidized the reducing substances present by the addition of 0.2 ml. of Br_2 solution (O_2 equivalent of Br_2 solution in 99γ of Br_2 per liter). After the bromine treatment they carried out the colorimetric modification of the Winkler method using tolidine together with $MnCl_2$, NaOH, and H_3PO_4.

Barnes (7) described a double syringe-pipette for use in the determination of dissolved oxygen. It consists of two reservoirs, one for the manganous sulfate solution and one for the alkaline-KI solution. Each reservoir is connected with a syringe through a 2-way stopcock. The other connection of each stopcock is to a delivery tube. The addition of the reagents from the syringes is controlled by a knurled screw. The apparatus was designed especially for field work and it is claimed that the precision obtained by this method is better than by standard techniques.

Lambert (35) and Nordling (44) both described the preparation of starch indicators to be used in the titration of iodine with thiosulfate. The former author prepared his indicator by dissolving 2.5 g. of linear potato starch fraction (which had been recrystallized twice from 1-butanol) in about 600 ml. of boiling water. The solution was filtered hot through fine filter paper. To the cooled solution he added 100 ml. of acetic acid (diluted to 200 ml.) and brought the volume to 1 liter. It is claimed that this indicator gives a sharper endpoint and 1 to 2 ml. is sufficient. The latter author prepared his indicator by bringing to a boil a mixture of 50 ml. of glycerol and 50 ml. of H_2O. One gram of starch in 2 to 3 ml. of water is added and the mixture boiled 3 min.

A modification of the Folin-Wu method for the determination of glucose in blood was introduced by Hindin (24) for the determination of lactose in dairy wastes. It was found that with all precautions taken the error did not exceed 10 per cent.

Organic Compounds

Headington *et al.* (22) discussed in a committee report the various methods for the determination of hydrocarbons. These methods included infrared measurement, benzene extraction, reflux distillation-extraction, extraction-pycnometer, and mass spectrometer procedures. In addition to the well-known methods for the determination of phenols, two

additional methods were developed as a result of the work of this committee. These procedures are the infrared and ultraviolet measurement of the phenol content of oil-polluted waters.

Berck (8) determined DDT in river water by adjusting the pH of a 1,500-ml. sample to 4.0–5.0. The sample is then extracted four times using 250, 200, 150, and 150 ml. of mixed solvent (peroxide-free ether and n-hexane 3:1 by volume). The time periods used for the successive extractions were 10, 8, 6, and 4 min., respectively. After a careful separation and evaporation of the solvent the color of the tetranitro derivative was developed according to the procedure of Scheehter and Haller. In analyzing suspended solids for DDT they were first dried and a portion extracted with Skellysolve F in a Soxhlet extractor. Color development was the same as for river water samples. The recovery of DDT from solids varied from about 71 to 87 per cent. The recovery from river water samples varied according to the ratio of DDT to water, the higher the ratio the lower the recovery.

In connection with a survey of a polluted stream Sutton (53) developed a method for the determination of pine oil in concentrations of 1 to 30 p.p.m. The method depends on the stable bluish-green color produced when pine oil is made to react with vanillin-HCl reagent at 60° C. for 25 min. The reaction actually determines alpha-terpineol, the chief component of pine oil.

Asmus and Garschagen (3) determined pyridine in water solution by its reaction with cyanogen-chloride for 5 min. in a stoppered flask. Following this reaction, 10 ml. of a 1 per cent aqueous solution of barbituric acid was added and after 30-min. contact the developed color was measured under ultraviolet light, using a Leitz filter No. 570. It is claimed that good results can be obtained when the pyridine concentration is between 0.5 and 150γ.

In the determination of hydrocarbons in industrial waste effluents and sewage Wedgwood and Cooper (58) first extracted the hydrocarbons with $CHCl_3$ and then removed the excess solvent. The dried sample was then redissolved in cyclohexane and chromatographed on an alumina column. The adsorbed hydrocarbons were then eluted with cyclohexane, using 3-ml. portions, and collecting 100 fractions. The hydrocarbons were estimated by determining the ultraviolet absorption spectra of each fraction. A table of characteristic absorption peaks is given in the original article.

Herd (23) used a fluorescent method for determining the identity of oil slicks occurring on water surfaces. One to three drops of the collected oil, dissolved in 50 ml. of ether, was allowed to ascend paper strips overnight. The particular oil present was then identified by means of fluorescent patterns under ultraviolet light. Increased resolution could be obtained by development of the paper strips with pure ether. This method has also been used to trace the presence of tar in sewers. Gilcreas *et al.* (17) used the "modified Sanderson" and the "semi-wet extraction" methods in their determination of grease in sewage. Both methods involve filtration of the sample through filtercel and muslin. The first method involves Soxhlet extraction on the filter residue, whereas the second method employs successive washing of the undried residue. Both procedures were checked by six cooperating laboratories using "Crisco" as a standard grease. The "modified Sanderson" method has a precision of $S = \pm 1.57$ on the basis of the recovery of 100.04 per cent of the grease in a 50-ml. sample. The "semi-wet" method has a precision of $S = \pm 2.64$ based on a 50-ml. sample and a recovery of 92.9 per cent.

Nusbaum (45), in the determination of phenols by the p-nitrosodimethylaniline method, removed interfering aromatic amines by means of an acidic ion exchange resin. A 0.1 per cent so-

lution of the oxalate of p-aminodimethylaniline was used as the color development reagent because of its increased stability.

Nitrogen Compounds

Anantakrishnan and Srinivasa Pai (2) carried out micro Kjeldahl determinations using as a digestion mixture H_2SO_4 and K_2SO_4 with various proportions of $CuSO_4$, HgO, and Se for varying lengths of time. For simple nitrogen compounds they found that in digestion for 5 min. after clarification using Cu and Hg as catalysts no loss of nitrogen occurred. However, when Se was used, a loss of nitrogen occurred which is ascribed to the dehydrogenation of NH_4^+ by the selenium catalyst. Baker (6) also noted the effect of selenium catalyst on the decomposition of NH_3 in the Kjeldahl digestion. Quantitative recovery of the nitrogen was obtained if the temperature did not exceed 420° C. during the digestion period. It was found that the digestion temperature was more critical than the digestion time. Fontana (16) found that only 70 per cent of the nitrogen present in nicotinic acid was converted to NH_3 in a 5-hr. digestion period with either Se or $HgSO_4$ as catalysts. Protein amino acids, including tryptophan, were decomposed in 3 hr. of digestion. In the preparation of Nessler reagent for the determination of ammonia, Yuen and Pollard (64) found that the best ratio of HgI_2: KI: NaOH was 1: 2.2: 20. In their ammonia determinations they used a Nessler reagent made by adding 22.72 g. of HgI_2 to 30 ml. of solution containing 18.26 g. of KI. This mixture is poured into a solution of 40 g. of NaOH dissolved in 950 ml. of NH_3-free water and diluted to 1 l. Two ml. of this reagent are used per 50 ml. of sample in the NH_3 determination.

Rand and Heukelekian (47) used zirconyl chloride as the base electrolyte in the polarographic determination of nitrates. The current is first measured at 1.2 v. against a saturated calomel electrode. Ferrous sulfate solution is then added, nitrogen is bubbled through, and the current again measured. The difference in current ($I_1 - I_2$) must be corrected for the Fe^{+++} ions present in the ferrous sulfate solution. The resulting ΔI is directly proportional to the nitrate present. The recovery of added nitrate to well waters and to trickling filter and activated sludge effluents was good. In the case of raw sewage, however, it was first necessary to determine ΔI in the usual manner. A known concentration of nitrate was then added and the current change again determined. From the relationship $\frac{\Delta I_1}{\Delta I_2} = \frac{C_1}{C_2}$ the concentration of nitrate in the unknown is calculated. Chow and Robinson (12) also applied the polarographic method for the determination of nitrates in sea water using UO_2^{++} ions. It was found that $SO_4^=$ depresses the reduction current by a definite proportion depending on the Cl^- content of the water. F^- also interferes with the reduction of NO_3^-, but this can be prevented by the presence of $AlCl_3$ or $ZrOCl_2$.

Metallic Ions

The separation of trace elements from natural waters often presents a difficult problem. Carritt (11) was able to obtain such a separation and concentration by means of a packed column made up of cellulose acetate carrying a carbon tetrachloride solution of dithizone (details for preparation of the column are given in the original publication). After adjustment of the sample pH to 7.0 ± 0.1, it is drawn through the column by means of vacuum. The dithizonates formed are eluted with either HCl or NH_4OH. Of the eight elements studied by this method, the concentration of all except manganese were determined polarographically.

Tammelin and Mogensen (55) determined calcium colorimetrically by its reaction with murexide in the presence of piperidine. The developed color is read spectrophotometrically at 510 mμ. Breyer and McPhillips (9) determined calcium in concentration between 1.3×10^{-4} and 1.2×10^{-2} M by reacting it with chloranilic acid, which precipitates calcium chloranilate quantitatively. The diffusion current of the unreacted chloranilic acid is determined polarographically and the calcium concentration determined from a calibration graph. The ions of Co, Zn, Pb, Mn, Cd, Ni, Al, Cu, and Ag interfere, as they also react with chloranilic acid. Harrison and Raymond (21) determined micro amounts of calcium by precipitation as calcium molybdate, conversion of this compound to molybdenum thiocyanate, and spectrophotometric measurement of the color produced. It is stated that 4 μg. can be estimated to ± 10 per cent, and it is claimed that the method is more precise than the oxalate or versenate method. Fe, Mg, Cu, and $PO_4^=$ do not interfere. Williams and Moser (61) determined calcium colorimetrically with purpurate. The dye solution, made by dissolving the purpurate in 70 per cent by volume of ethyl alcohol, is stable for about 8 hr. at room temperature. The calcium-purpurate curve is linear for calcium concentrations from 0 to 1.2 p.p.m. The color development is carried out at pH 11.3 and the absorbancy read at 506 mμ. Ferric iron in concentrations of about 1 p.p.m. interferes. In the determination of calcium and magnesium by the Schwarzenbach reaction, Jenness (30) showed that the presence of phosphate interferes with the end point. He eliminated this interference by passing the sample through an anion exchange column of Duolite A–4 resin. Although the method was used in the determination of calcium in milk samples, the same procedure can be applied to water samples containing phosphate.

Dirscherl and Breuer (14) determined magnesium colorimetrically by means of Eriochrome Black. The calcium present is first precipitated as the oxalate. To the clear supernatant, 2.5 ml. of 0.1 N KCN and 1.0 ml. Eriochrome Black was added. The resulting color was measured photometrically using filters S53 and S66 against a blank. Harvey *et al.* (18) made use of this same procedure for the determination of magnesium. The calcium was precipitated as the sulfate in the presence of methanol. Not more than 5 mg. of calcium and 1.2 mg. of magnesium should be present. A methanol solution of Eriochrome Black T is added, the amount depending on the concentration of magnesium present. The absorbancy of the colored complex was measured at 520 mμ. The method can be used for magnesium concentrations from 0.2 to 14 p.p.m. and the values obtained checked closely with those obtained by the gravimetric procedure.

In the determination of iron in river samples by the thiocyanate method, Houlihan and Farina (26) found that the addition of 3 drops of H_2O_2 to a 100-ml. sample stabilized the ferric thiocyanate color. This stability lasted for about 5 hr. and after fading could be restored by the addition of more H_2O_2. By measuring the color both before and after the addition of the H_2O_2, both ferrous and ferric iron could be determined on the same sample. Lieber (38) determined total iron in the field by the addition of 20 ml. of 50 per cent H_2SO_4 to a 30-ml. sample. A few drops of $KMnO_4$ (6.3 g. per liter) are then added to produce a pink color for 1 min., followed by 5 ml. of KSCN solution (300 g. per liter). The color is compared immediately with permanent standards made up with various amounts of K_2PtCl_6, $CoCl_2$ and $CuCl_2$ solutions. Simons *et al.* (51) found that the σ-phenanthroline method was not suitable for the determination of iron in sea water. For the determination of

Al they used a 0.01 per cent solution of Blue Black R in 95 per cent ethanol as a fluorescent indicator. The color reaction was carried out at pH 5.0, the fluorescence measured after 2 hr., and its intensity compared to standards.

In the determination of copper with diethyldithiocarbamate, nickel is one of the interfering elements. Jewsbury (31) removed the nickel as a chelate with ethylenediaminetetraacetic acid. The excess of this reagent was removed with $MgSO_4$. The method will also remove other metal ions which form chelates with this compound (Bi, Hg, and Ag are not removed). Skibina (52) determined copper in the concentration range of 0.025 to 5 γ by reacting it with phenylsemicarbazide in the presence of NH_4OH. The reaction is carried out by the addition of 0.6 ml. of the reagent to 4 ml. of sample, the mixture heated to 91° to 92°, and after cooling 1 drop of NH_4OH is added.

A turbidimetric method for the determination of zinc was proposed by Mayne and Noordhof (39). The method consists of the reaction of zinc with sodium diethyldithiocarbamate in the presence of polyvinyl alcohol as a protective colloid. The absorption is proportional to the zinc content in the range 0 to 10 p.p.m., with an accuracy of about $\pm$ 0.05 p.p.m. Iijima and Hashimoto (28) determined zinc by reacting it with a mixture of *p*-aminophenol and $K_3Fe(CN_6)$. The red color formed followed Beers' law and as little as 0.54 γ per ml. of Zn could be determined.

The difficulties encountered in the determination of beryllium in biological materials are pointed out by Toribara and Sherman (56). The steps necessary for the recovery of Be include precipitation, electrolysis with a mercury cathode, ion exchange absorption, and finally complexing with acetylacetone. The authors discuss various procedures for the determination of Be, including colorimetric, fluorimetric, and spectrographic procedures.

Mokranjac and Rasajski (40) used a modified Gutzeit procedure for the determination of traces of arsenic. The modification consisted of using an $AuCl_3$ impregnated paper, the evolved AsH_3 liberating metallic gold in proportion to the As present. Different sizes of paper are used according to the amount of As in the sample.

Halogens

Asmus and Garschagen (4), in their further work on the determination of chlorine, still used the formation of cyanogen bromide as a basis for its determination. In their new procedure, they added an aqueous solution of pyridine and barbituric acid to the preformed cyanogen bromide, thus forming the complex barbiturie acid derivative. The resultant reddish-violet color was measured spectrophotometrically at 578 mμ. The method is sensitive to 0.05 γ of chlorine. In the termination of chlorine in the atmosphere Krivoruchko (33) aspirated the air through 2.0 ml. of 0.000055 N methyl orange containing 0.1 ml. of 0.05 N H_2SO_4. The resultant color was compared with standards made with known amounts of chlorine.

Sulfur Compounds

In the volumetric determination of SO_4=, Hunt (27) first removed metal ions by passing the sample through a resin column of Amberlite–IR–112. An excess of standard $BaCl_2$ solution is added (approximately double that needed to precipitate the SO_4=) and this excess is then titrated with ethylenediamine tetraacetic acid. Since this end point is not sharp, a standard $MgCl_2$ solution is added and the titration continued. The procedure is especially suitable for sulfate determinations in waters high in the alkali metals

and also for very hard waters. In a qualitative test for sulfides, Mueller and Rand (41) used about 1 ml. of sample on a watch glass. To this was added 1 ml. of 30 per cent NaN_3 and 1 ml. of 0.1 N I_2. If sulfides are present, bubbles of nitrogen gas can be observed in 2 to 5 min. Although a sensitivity of 0.1 p.p.m. of sulfide is obtained, thiosulfates and thiocyanates must be absent. Wilson and Smith (62) designed a cell for the continuous polarographic determination of sulfites in corn steep liquor. A study was made of the effect of cell design and flow rates (0 to 1,000 ml. per minute) on the diffusion current. The results obtained by this method checked quite closely those by the iodimetric procedure.

Phosphorous Compounds

In the determination of phosphorus in biological growths, Harvey (19) converted the P to PO_4= by heating with H_2SO_4 until charring occurred. After the addition of one drop of 30 per cent H_2O_2, the regular Mo-blue method is used. The author points out the extreme sensitivity of the method and the precautions that must be observed. Takahashi (54) determined soluble phosphorus by the addition of $HClO_4$, metal reagent (a mixture of p-$MeHNC_6H_4OH$ and $NaHSO_3$), and NH_4molybdate to the sample and reading the absorbancy after 55 min. For the determination of total phosphorus, the sample was first treated by heating with $HClO_4$ and H_2O_2.

Cyanogen Compounds

The determination of free cyanide was carried out by Kruse and Mellon (34) in a solution buffered at pH 6.8. Chloramine-T was used to convert the cyanide to cyanogen chloride, after which color development was by means of the pyridine-pyrazolone reagent. Total metal cyanide was determined by adding the sample (containing versene for metal complexing) to a boiling phosphoric acid solution. The liberated HCN was distilled into either a water or sodium acetate solution, followed by color development as free cyanide. The separation of cyanide from thiocyanate was made by extraction of the cyanide from an acetic acid solution with four 40-ml. portions of isopropyl ether. The HCN is then re-extracted with 3 per cent NaOH, the caustic extract neutralized, and the color developed. Thiocyanate was determined by adjusting the sample pH to between 2.4 and 4.0, adding $CuSO_4$ and pyridine, followed by extraction with chloroform. The absorbance of the chloroform extract was determined at 410 mμ.

Instrumentation

Papers by Wyatt (63) and Murray (42) and an ASTM symposium (5) on instrumentation are of special interest to those working in the field of sanitary chemistry.

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SEWAGE

Sedimentation and Mechanical Filtration

Daniels (37) proposed suspending baffles below the surface from the flight members of a regular primary tank sludge collection mechanism. The area-zone "protected" by these baffles and their velocity determines the flow rate of the tank. It is claimed that this proposal will confine the flow, produce uniform flow, and allow a smaller tank.

Evans and Roberts (45) reported the results of investigations carried out at the Luton (England) sewage works on the operation of sand filtration and microstraining plant. The settled trickling filter effluent was passed through sand filters and microstrainers to produce an effluent of very high quality, with suspended solids less than 30 p.p.m. in order to meet special stream requirements. The results of 12 months experience showed that sand filters reduced the suspended matter content of the effluent by 75 per cent and B.O.D. by 52 per cent. The microstrainers reduced the suspended matter by 66 per cent and B.O.D. by 36 per cent. Both units required a good quality of applied effluent in order to maintain a suspended matter of 5 p.p.m. or less in the final effluent.

Biological Filters

A paper by Kilgore and Sawyer (87) has revealed some of the nutritional requirements of high-rate filters when fed industrial waste-domestic sewage mixtures containing varying quantities of nitrogen and phosphorus. In this study two-stage, high-rate, 3-ft. deep trickling filters were fed industrial waste-domestic sewage mixtures at daily loadings ranging from 1.35 to 3.24 lb. B.O.D. per cu. yd. Wastes used were a bleachery waste, a cotton kiering waste, a rag-rope pulp cook waste, and a rope pulp cook waste. It was found that in the presence of excess nitrogen and phosphorus constituents, the nitrogen requirements of the treated mixtures varied from 4.7 to 7.4 and the phosphorous requirements varied from 0.36 to 1.25 lb. per 100 lb. of B.O.D. removed. It was also shown that cotton kiering liquors may be successfully treated on high-rate two-stage trickling filters when diluted with as little as 5 per cent of sanitary sewage. A nitrogen deficiency resulted in little impairment in the operating characteristics of the high-rate filter up to B.O.D.: N ratios of 40. Ratios greater than this resulted in decreased efficiencies of B.O.D. removal. A nitrogen deficiency in the treated waste was found to retard the maturing of filters. In general, these tests served further to demonstrate that high-rate trickling filters are resistive to shock loadings in that they will operate efficiently for short periods when extreme nutrient deficiencies exist.

In a series of tests on four 4-ft. sq. experimental trickling filters, Sorrels and Zeller (140) investigated the ratio of soluble to insoluble B.O.D. in a domestic sewage and determined the quantities of each removed by the experimental filters. The average B.O.D. loadings on the filters were 431, 630, 953, and 1,420 lb. per acre-foot per day, with the corresponding hydraulic rates 1.7, 2.4, 3.7, and 5.5 m.g.a.d. The soluble and insoluble B.O.D. fractions of the applied sewage were determined by separation in a Gooch filter, and it was shown that the soluble B.O.D. of the sewage averaged one-half of the total B.O.D. Test results showed that for loadings of applied total B.O.D. from 100 to 1,000 lb. per acre-foot per day, removals of soluble and insoluble B.O.D. were approximately equal. However, loadings of a higher rate indicated a rather sharp decrease in the percentage removals of both fractions. Removal of suspended solids by the filters followed the same general trend.

Rankin (125) evaluated the performance of eight trickling filter plants by the Velz formula, the Tentative Standards method, and the National Research

Council formula. The data used in the analyses were obtained from eight representative municipal plants and covered periods of operation ranging from 3 days to 24 months, the plants being widely scattered geographically. Comparisons were made on the basis of actual percentage efficiency of B.O.D. removal as compared with the efficiency computed by the three methods. Comparisons of the efficiency of single-stage and two-stage plants with the filters in series indicated that the Velz formula for computing performance checked the actual results most accurately, but the ease of application of the Tentative Standards method appears to make it the method of choice. The author concluded that measures of performance of biofiltration plants can be defined which are applicable to economic designs of new plants and which permit the prediction of results with a satisfactory degree of assurance. Borden (20) described in some detail three high-rate trickling filter plants having different depths and kinds of filter media and subjected to different rates of recirculation. Data presented indicate that each plant is doing a satisfactory job of B.O.D. and suspended solids removal from the raw sewage, with over-all B.O.D. removals ranging up to 95 per cent. Although the author states that the efficiency of removal can be predicted within a very small range, he does not explain the method of arriving at this prediction.

In a discussion as to the merits of various depths of trickling filters, Imhoff (72) pointed out that in German practice the economical depth is between 2 and 4 m. However, depths up to 8 m. are used in that country. Regardless of depth, the surface loading of trickling filters should not fall below 0.8 cu. m. per hr. per sq. m. (20 m.g.a.d) of surface area, even where recirculation of the effluent is necessitated.

Tomlinson and Hall (149) summarized and analyzed the results of three years of operation of trickling filters in regard to the following points: (a) the effect of alternating double filtration, filtration with recirculation of the effluent, and filtration of the effluent from a bio-flocculation plant; (b) the effect of the rate of rotation of the distributors; and (c) a comparison of treatment by single, double, and alternating double filtration and by filtration with recirculation of the effluent. The first two series of experiments were conducted using four circular filters 120 ft. in diameter and 6 to 7 ft. deep. The third series was carried out using eight small-scale filters having a depth of 6 ft. and a surface area of 36 sq. ft. each. Comparison of the results obtained in (a) at an average dosing rate of 150 g.p.d. (Imp.) per cu. yd. indicated that alternating double filtration produced effluents of lower B.O.D. values than filtration with recirculation on a 1:1 ratio or filtration of effluent from a bio-flocculation plant. Reducing the rate of revolution of rotary distributors from one revolution in 15 sec. to one revolution in 8 min. resulted in an improvement in the quality of effluent and reduced ponding of the filters during winter operation. The series of experiments using the pilot plant filters operated at 240 g.p.d. (Imp.) per cu. yd. indicated that double filtration, alternating double filtration, and filtration with recirculation produced final effluents of the same quality. Other experiments on alternating double filtration have been reported by Oldroyd (113) using 6-in. diameter laboratory-scale filters, 5.25-ft. diameter pilot-plant filters, and a full-scale trickling filter dosed by a rectangular distributor. The sewage treated contained approximately 40 per cent textile trade wastes. All told, it was found that alternating double filtration with daily alternations gave slightly better results than recirculation of the effluent. It was also found that on the plant-scale filter it was possible to treat settled sewage at a

rate of 500 g.p.d. (Imp.) per cu. yd. with no deterioration of the effluent quality. In alternating double filtration, the omission of a settling tank after the filtration through the primary bed affects the quality of the final effluent only slightly according to Tomlinson and Hall (150). The suspended solids from the final tank is somewhat increased.

Biladeau (17) described a conventional trickling filter installation used for reducing the level of radioactivity in a domestic sewage. The filter is 5 to 10 ft. deep and contains rock of 2- to 3-in. diameter. The plant is designed so that the trickling filter will receive 1 m.g.a.d., which is supplemented by a minimum recirculation ratio of 5 to 1. This rate of recirculation has been found to produce the most satisfactory absorption of radioactivity from the settled sewage.

Continuing experiments at Minworth (126) on the effects of periodicity of dosing of trickling filters showed that reducing the rotational speed of four-arm distributors to one revolution in 15 to 30 min. results in a greater efficiency of B.O.D. removal than that obtained at higher rates. The tendency towards ponding is also reduced with lower rotational speeds. Parallel observations indicated that omission of the settling tanks between the trickling filters in alternating double filtration plants causes only minor deterioration in the final effluent. Studies of the high-rate single filtration process proved that the chief difficulty of operation resulted from accumulation of large amounts of biological film in the upper layers of the medium giving rise to ponding difficulties. Experiments have shown that when filtering medium of 1.5- to 3-in. size was used it was not necessary to fork the filters to prevent ponding, whereas forking was necessary when 0.75- to 1.5-in. medium was used. The rate of loading ranged from 450 to 1,000 g.p.d. (Imp.) per cu. yd. The weight of B.O.D. removed per day per cubic yard of medium was about the same for the two sizes of medium employed. Some attention also was given to determining factors which influence the rate of growth of fungi found in greatest abundance in trickling filters treating sewage. These included *Fusarium aqueductum*, *Sporotrichum*, *Oospora fragrans*, and *Sepedonium*. The factors studied were: (a) optimum range of pH; (b) oxygen requirements; (c) growth activity resulting from various sources of nitrogen; (d) vitamin requirements; and (e) the effects of tracer elements, including Ca, Fe, Zn, Cu, Mn, B, Co, Mo, Ni, Br, and I.

The operation of a deep (18 ft.) 52-ft. diameter enclosed filter was reported by Cameron and Jamieson (26). The stone was graded so that the top and bottom 1-ft. levels had coarse media and the 14-ft. section stone of 1½- to 2-in. size. Results from 7 years operation are given. Dosage rates varied from 70 to 460 g.p.d. (Imp.) per cu. yd. and organic loading from 0.1 to 8 lb. per cu. yd. per day. The ponded filter did not improve by recirculation; even after starting with a nonclogged filter ponding was not prevented by 1:1 recirculation. Samples taken at various depths showed that a high proportion of the removal was performed in the first 9 ft. of media. The filter was also used as a roughing filter for partial treatment. Forced aeration by a fan did not improve the purification, except possibly nitrification.

Activated Sludge

Pasveer (117) studied the factors affecting the transference of oxygen from the atmosphere to the activated sludge floc and concluded that when particles reach a certain size, oxygen will not penetrate the floc even when the concentration of oxygen in the liquor is high. With large floc particles, the relative active volume for biochemical oxidation is reduced. Pasveer (118) (119) determined the rate

of oxygenation under fixed conditions experimentally and with the use of Kessener brush aerators found values of 1,700 to 2,100 g. per kilowatt-hour. The rate of diffusion of oxygen in water is inversely proportional to the square root of the aeration time. Smith (138) developed a new method for the indirect measurement of activated sludge oxygen utilization. For synthetic sewages, the average oxygen concentration of an activated sludge liquor between 0.2 and 6 p.p.m. did not significantly affect the unit rate of oxygen utilization. This unit rate decreases with increasing solids concentration and with increasing sludge age. The various proposed relationships between temperature and activated sludge efficiency were reviewed by Krause (89), who found great differences in the equations proposed.

In studies of the biology of activated sludge, Baines *et al.* (12) found that although the B.O.D. of the effluent was inversely proportional to the number of peritrichous ciliates in the sludge, the relationship between protozoan numbers and sludge conditions or effluent quality cannot be expressed quantitatively. McKinney and Weichlein (106) isolated and identified several bacteria which upon aeration produced floc characteristics of activated sludge. From microscopic examinations, they concluded that the floc formation was the normal result of complete metabolism of substrates and not the product of special zoogleal-forming bacteria. In bottle experiments, McKinney and Poliakoff (105) found that biocatalysts such as concentrated bacteria or enzymes did not increase the rate at which biochemical equilibrium was established or the rate of B.O.D. removal. Pillai *et al.* (120) found that all bacteria in cultures of *B. typhosum*, *Shigella paradysenteria*, and *Vibrio cholerae* were killed when they were aerated by sterile air with fresh settled activated sludge, raw sewage, sterilized sewage, and pure cultures of *Epistylis* in sterile sewage. Pillai, Prabhakara Rao, and Mohan Rao (121) reported that as little as 40 p.p.m. of aureomycin in a sewage-activated sludge mixture adversely affected the clarifying power of the sludge as measured by the $KMnO_4$ oxygen consumed test. Protozoa in the sludge were largely inactivated, but the bacterial content was not appreciably affected. Streptomycin in doses of 100 p.p.m. also interfered with clarification. With penicillin, the activity of the sludge was not appreciably affected. Kocher and Corti (88) analyzed for vitamin content samples of sludge which had been dewatered by centrifuging or dried at 105° C. The following results are reported in milligrams per 100 g. of dried sludge:

	Centrifuged	Dried
Aneurine	2.05	0.63
Lactoflavin	2.16	1.3
Adermin	Trace	0.7
Nicotinic acid	13.6	10.0
Pantothenic acid	4.6	4.4
Biotin	158	83.4
Folic acid	182	140
Vitamin B_{12}	159	100

The removal of dissolved or filterable solids from sewage by activated sludge is much slower than is the removal of suspended material. Horasawa (69) found that only 20 per cent of the dissolved solids were removed during 2-hr. aeration and concluded that removal of dissolved solids is accomplished by biological absorption, whereas suspended solids are physically absorbed. The growth of floc is primarily brought about by dissolved solids. Gould (53) reported that with modified aeration, only about 50 per cent of the filterable B.O.D. is removed, so that with a larger proportion of filterable B.O.D., lower over-all removals could be expected.

Gould (53) also discussed some of the important developments in design and practice in New York City. All of the conventional activated sludge plants are now equipped for step aera-

tion and provision has been made in most of them for modified aeration. With step aeration, only about one-half the aeration tank capacity is needed to obtain the same over-all results as with conventional activated sludge plants. With modified aeration, 80 to 85 per cent removal of suspended solids and 75 to 80 per cent removal of B.O.D. are obtained. In an excellent report, Wuhrmann (166) described the large-scale high-rate activated sludge experiments at Zurich. He obtained up to 82 per cent removal of B.O.D. at loadings of 195 lb. of B.O.D. per 1,000 cu. ft. of aerator capacity per day. The effluents averaged about 25 p.p.m. B.O.D. At these high loadings, the aeration solids varied from about 2,400 to 3,600 p.p.m. and the aeration periods from about 30 min. to a little more than 1 hr. The addition of asbestos had little effect on purification. Edwards (42) reviewed the treatment principles of various modifications of aeration and activated sludge processes and classified them according to sludge age and purification expected. Okun (112) believes that the cheap production of tonnage oxygen, which is about 95 per cent pure, may be the basis of a new bioprecipitation process.

The effect of storing activated sludge in the absence of air was studied by Keefer and Meisel (83), who found that best purification was obtained when fresh activated sludge was used. If aeration was stopped for a few days, or even hours, an appreciable reduction in B.O.D. removal resulted upon resuming aeration, but normal B.O.D. removals were obtained after an extended aeration period, the length of which depended on the duration of the shutdown. When aeration was stopped, the oxidation-reduction potential decreased rapidly at first and then tended to level off. The E_h reached zero in 15 hr. to 3 days. Nussberger (111) discussed the application of oxidation-reduction potentials to the control of aeration in conventional and step aeration plants.

Toxic metals, such as copper and zinc are readily removed by activated sludge. Rudolfs and Zuber (132) found that the amount of metal removed is a function of the concentration of the sludge, the contact time, and the character of the sludge. The organic content of the sludge seemed to be responsible for the removal of the metals. Husmann (71) found that supersonic treatment for 15- and 30-min. periods caused activated sludge to deteriorate. As it became finely divided and settled less rapidly, the effluent or supernatant liquor had a higher oxygen consumption.

Disinfection

The fundamental chemistry involved in sewage and industrial wastes chlorination is shown to be complex (110). This is due primarily to the fact that numerous germicidal chlorine derivatives of varying effectiveness are formed. Wilson (164) emphasizes that methods used in water chlorination are not usually applicable to sewage treatment. A review of published data reveals discrepancies in the effect of sewage chlorination.

Ammonium chloride may increase the bactericidal efficiency of hypochlorite, Halozone, and Chloramine T in the presence of organic material. The ammonium ion apparently exercises a buffering action, permitting the chlorine to form chloramines instead of immediately attacking the organic matter (52). Possible application of oxidation-reduction potential in measuring the effectiveness of chlorination is discussed by Frers (48). Formulas for determining the oxidation-reduction potential are given and the role of pH in chlorination is discussed.

Three groups of laboratory tests performed at Baltimore involved chlorination of raw and treated sewage. Keefer and Meisel (84) provided data giving oxidation-reduction potentials of raw

sewage and sewage plant effluent treated with different amounts of chlorine. Results indicate a general relationship between the E_h potential of the sewage and chlorine residual determined by neutral starch-iodide.

Inactivation of the poliomyelitis virus with chlorine is possible with free residual chlorine. The necessity for destruction of the virus in sewage is doubtful, due to lack of evidence proving poliomyelitis to be a waterborne disease. Operators of sewage treatment plants should be alert for improved procedures and include them, where possible, in plant operation (91). Heavy chlorination is required in New Hampshire to meet requirements of 90 per cent of the surface waters in the state. Statutes dictate that waters of bathing quality shall not receive wastes containing more than 240 M.P.N. coliform organisms per 100 ml. (49).

Statistical analyses of plant data and the theoretical aspects of sewage chlorination as it effects bacteria are given by Hess *et al.* (61). Statistical methods were used to compare data from treatment plants under jurisdiction of the Interstate Sanitation Commission. A relationship is given which will permit the use of curves to estimate the chlorine residual required to maintain any given M.P.N. within required limits. A theory of bacteria kill in sewage disinfection is given (62) and some of the factors which complicate the mechanism of sewage chlorination are revealed.

Hypochlorous acid, monochloramine, and chlorine dioxide were studied in an attempt to learn why these compounds are effective as bactericidal agents. It is suggested that hypochlorous acid and chlorine dioxide form an irreversible product with the sulfhydryl radical. Monochloramine apparently fails to complete the oxidation reaction immediately, explaining in part why higher residuals and longer contact periods are required for disinfection with monochloramine (74).

Three different types of sewage were used in the evaluation of chlorine residual determination methods. Statistical analysis reveals that the amperometric method gives higher values for residual chlorine than ortho-tolidine does for identical dosages. The residual difference is apparently proportional to the amount of organic matter present, but M.P.N. reduction is the same for a given chlorine residual by amperometric and ortho-tolidine methods (38). A sub-committee of the FSIWA Committee on Standard Methods reports progress in providing an analytical procedure for residual chlorine in sewage containing industrial wastes (65). Statistical plots of a preliminary study show minor superiority among the ortho-tolidine, amperometric, and acidified starch-iodide residual chlorine methods when coliform M.P.N. is considered.

Methods for treating sewage from tuberculosis sanitoria include septic tanks and seepage pits where appropriate, but mechanical and biological treatment plus dilution, chlorination, or sand filtration is generally required (133). Chlorine gas or liquid chlorine is preferable for disinfection. Alkaline hypochlorite solutions are not germicidally effective for *B. tuberculosis*. Sludge digestion does not eliminate tubercle bacilli and should be followed by prolonged drying, hot composting with lime, or crude calcium cyanamide.

Chlorine handling received attention during 1953, with activities of the Joint Committee on Chlorine Supplies recommending procedures to be followed in the use of chlorine (9). The report includes conditions of use for chlorine cylinders and ton containers, chlorine inventories, transportation, return of empty containers, and safety practices.

Information is given concerning standby equipment and emergency procedures, together with chlorine equipment manufacturers, chlorine producers and repackagers. Basic princi-

ples for chlorine handling are discussed (90) including chlorine packages, feeders, gas masks, and hypochlorites. Kavanaugh (79) points out that proper chlorinator installation should be followed by proper maintenance. Operators should become as familiar as possible with chlorinating equipment, and be alert for chlorine leaks and correct them immediately.

The storage of tank car lots of liquid chlorine is under study by the Joint Committee on Chlorine Supplies and the Public Health Advisory Committee of The Chlorine Institute, Inc. Woodward and Hedgepeth (165) believe that stationary bulk storage of liquid chlorine ". . . is practical and feasible under the right conditions and with proper precautions." Properties of liquid chlorine are discussed, together with recommendations for storage vessel specifications. Air padding, inspection, and servicing are discussed from the standpoint of continuous safe operation. Bulk storage of liquid chlorine in 50-ton and 40-ton stationary tanks is provided at the new North Point and Southeast primary sewage treatment plants in San Francisco, Calif. Chlorine is purchased in 30-ton tank cars, stored in the bulk tanks and withdrawn as a liquid to vaporizers. Gas from the vaporizers is metered by chlorinators in the usual manner. A specially trained two-man unloading crew is assigned the task of transferring liquid chlorine from railroad tank cars to the storage vessels. All personnel have been trained and are qualified to act in an emergency (14).

Sewage may be disinfected by exposure to ionizing radiations from Co^{60} and cathode ray sources. Dunn (41) performed laboratory experiments on 5-ml. samples using kilocurie Co^{60} and a Van de Graaff generator as radiation sources. Results indicate high percentage bacterial reductions when samples were exposed to Co^{60} radiations for 125 min. and to cathode rays for 10 sec. or less. Environmental factors which affect colloidal silver as a disinfectant have been investigated by Chambers *et al.* (29). They report neutralization of the disinfectant by *l*-cystine, effective bactericidal action from 0.1-p.p.m. concentration at pH 8.5 to 9.0, and reduced germicidal activity at 2° to 5° C. The bactericidal efficiency of the silver compound tested appeared to deviate from patterns generally associated with phenolic and halogen compounds. Hoffman *et al.* (66) investigated the bacterial action of Movidyn, a colloidal silver preparation. Time-dilution studies reveal an initial rapid death rate and a secondary slower death rate, a phenomenon typical of many disinfectants. Secondary rates for *E. coli* exposed to a 1 : 20,000,000 dilution of Movidyn were found to be higher as the temperature increased from 4° to 39° C. *E. coli* were killed more rapidly at a 1 : 1,000,000 dilution than at 1 : 20,000,000. The material exerts a residual effect which does not rapidly disappear.

Taras (148) reports a study of nitrogen as a factor following chlorination. Thirty-three compounds containing nitrogen were chlorinated to insure a free available chlorine residual of 0.5 p.p.m. after 24-hr. contact. Samples were dechlorinated at the end of 1 hr. and 24 hr. so that nitrogen losses could be determined. Simple and unsubstituted amino acids were relatively rapidly converted to a form undetectable as albuminoid nitrogen. Total nitrogen conversion was appreciable, but seldom exceeded 75 per cent of the total nitrogen originally added. Chlorination appeared to have only slight effect on the nitrogen transformation of proteins, whereas the ammonium ion loses nearly 90 per cent of its identifiable nitrogen under the same conditions. Ammonium ion and albuminoid nitrogen frequently account for 75 per cent of the chlorine demand of Detroit sewage and establish a relationship which can be plotted. When chlorine and nitrogen demand are plotted

logarithmically against contact time, parallel lines result if ammonium ion concentration is high. Non-parallel lines occur when organic nitrogen predominates, the effect normally exhibited by raw water at Detroit.

Sludge Digestion

Theory and Mechanism

The development of present knowledge of the sludge digestion process was discussed by Coulter (35) and the principal environmental factors in anaerobic digestion evaluated. Interference with either methane fermentation from volatile acids and alcohols or the hydrolysis of complex organic compounds causes a loss in gas production. Laboratory experiments are cited which show a 76 per cent increase in gas and a 30 per cent increase in B.O.D. reduction as a result of the seeding and other effects of agitation of digesting sludge. Little methane is produced outside a pH range of 6.2 to 8.8; 2,000 to 3,000 p.p.m. alkalinity is beneficial to digestion; and 500 to 600 p.p.m. ammonia is conducive to good digestion of carbonaceous materials. Buck, Keefer, and Hatch (24)(81)(82) reported the results of experiments on the nature and identity of various organisms responsible for sludge digestion. *Streptococcus diploidus,* an organism not previously reported, was isolated from actively digesting sewage sludge in a treatment plant. No medium was found that the organism would ferment or from which gas was produced. In raw sludge the organism produced gas, but no gas developed when sterile sludge was the substrate. It is considered probable, therefore, that the *S. diploidus* functions in synergism with other organisms. Raw sewage sludge seeded with the organism was digested at 35° ± 0.5° C. over a wide pH range. A control was seeded with digested volatile solids and maintained at pH 6.8. Forty-nine days were required for digestion at optimum pH of 7.6, compared with 31 days for the control (pH 6.8). Whether *S. diploidus* is a key organism in digesting sewage is not determined. It can be described as a liquefying, facultatively anaerobic, non-pathogenic, Gram-positive, non-spore forming coccus that grows in lumps or chains at an optimum temperature of 35° C. and an optimum pH of 7.6.

Proprietary additives claimed by manufacturers to hasten digestion, reduce scum, etc., were studied in controlled experiments by Heukelekian and Berger (63). It was found that (a) the addition of enzymes, bacterial cultures, or yeast did not increase the liquefaction of non-sterile fresh solids as measured by the B.O.D. of the supernatant liquor; (b) pure enzymes in fresh sterile solids increased the B.O.D. of the supernatant; and (c) the addition of enzymes to settled sewage did not result in increased stabilization, nor did it affect B.O.D. after storage up to six days. Vilen (155) ran a bottle digester experiment to test the claims of a manufacturer of enzymes. On the basis of a single experiment the results showed some 5 per cent increase in gas production. The author, however, considers that the cost is too great, and warns against generalizing from one experiment.

Thermophilic digestion of sludge on a laboratory scale was tested experimentally by Keller (86) as a means of destroying or inactivating the ova of parasitic worms and the cysts of amoeba parasitic to man, which are commonly found in sewage at all stages of treatment. Thermophilic digestion for 24 hr. killed all parasitic ova and cysts. Heat treatment of sewage sludge digested at mesophilic temperature was also investigated. It was found that prolonged exposure of sludges to 37° C. completely inactivated ova of *Ascaris lumbricoides,* but the process was considered impractical because of the time required. Heating of digested or raw

sewage sludge to 55° C. for 2 hr. destroyed all parasitic ova and cysts.

In Waterbury, Conn., large enough amounts of copper in the sewage were reported (109) to make sludge digestion impractical. The adsorption of radioactive materials was reported (160). Primary sludge adsorbs only small amounts of isotopes of sodium, phosphorus, cobalt, bromine, and iodine. In secondary sludge, isotopes of phosphorus and cobalt are strongly adsorbed. The long life of cobalt may be serious.

Pillai and Rao (122) made chemical and microscopic examinations of decomposing sewage sludge from Calcutta. They found inexplicably high concentrations of nitrogen in sludge gas and of silica in sludge. No nonbacterial life was observed, but when sludge was inoculated into sterile sewage and aerated, 2,400 *Vorticella* per ml. developed in 44 hr.; when distilled water was substituted for sterile sewage only 44 *Vorticella* per ml. developed. Clark and Fina (31) found that methane-producing bacteria from actively digesting sewage sludge are capable of utilizing benzoic acid as their sole source of carbon under anaerobic conditions. In South Africa (141), strains of sulfate-splitting bacteria from anaerobic digestion of distilling wastes have been isolated in order to study their action in anaerobic corrosion.

A new phenomenon was noted by Carlson (27). In laboratory experiments an alternating current of 40 ma. passed through flasks of digesting sewage increased the production of gas by 100 per cent. Since 80 ma. was not as effective, temperature cannot account for the results. The acid fermentation stage lasted 8 days, as compared to 33 days for the control. The anaerobic bacteria count was 2.5 times greater, and $KMnO_4$ consumption was less than half that of the control after 14 days.

Operation, Maintenance, and Efficiency

Palocsay (115) described experiences with Imhoff tanks in Cleveland which had been converted to secondary digesters by adding floating covers and gas collection equipment. Investigation of the original 3-in. heating coils revealed scaling and deposits of such extent that in 5½ years the heat transfer value had dropped from 7.9 to 4.4 B.t.u. per hour per square foot per degree of temperature differential. After the coils were cleaned the heat transfer coefficient increased substantially, but soon dropped again. At best the heated sludge showed temperature variations from 4° to 18° in zones from top to bottom of the tank, with cold spots at various locations. External heat exchangers were adopted as a result of careful study. In Hartford, Conn., however, Locke (94) found that heating coils needed cleaning only after 12 years. Sludge was readily knocked off the pipe after hot water was circulated to dry the incrustation; and coils and supports were found to be very little corroded. After cleaning, the heat transfer coefficient more than doubled. Allison (3) experienced failure of heating coils in 8 months and of digester mechanisms in 14 months due to electrolysis in which the reinforcing steel in the tank wall served as a cathode and the heating coils as an anode. Fluorides are reported as responsible. After cathodic protection was installed the life of replaced equipment was 9 years. Edwards (44) described the conditions in a digester cleaned at Gowanda, N. Y. Heavy silt was found in the bottom, and sand and inorganic materials around the periphery of the tank away from the sludge paddles. The gas dome was in bad condition, but the coils and mechanisms were intact. Failure of protective coatings in gas domes was reported by Quartly (124). Hagerty (58) described the failure of roofs on floating covers due to condensation of moisture

on the under side leading to rotting of the wood.

Several authors described experiences with starting digesters initially or after cleaning. One of the most successful was reported by Brunner (23), who put a cleaned tank back into operation by filling it with raw sewage, then adding large amounts of digested sludge and heating the mixture to 90° F. Raw sludge was then added and a smooth takeoff resulted without the development of acid-stage digestion. To accomplish the same result, Edwards (43) recommended leaving 1.5 ft. of sludge for seed in a digester being cleaned. Benas (15) described the starting of primary digesters at San Francisco, where 1 m.g. of digested sludge was hauled from another plant in 5,200-gal. tanks. The digester was filled with water and heated to 95° F. as digested sludge was being added. When 500,000 gal. of seed had thus been introduced, raw sludge was added in amounts equal to 10 per cent of the solids loading in the digester. Digester supernatant and excess sludge were transferred to two other digesters. In 30 days the digester was functioning. Six days after feeding with raw sludge the gas produced was in scale with the raw solids added. This method was impractical at the Hyperion plant in Los Angeles, according to Parkes (116), because of the large volume of the digesters in comparison with seed. Steam was used to heat raw sludge and satisfactory methane production began in 4 to 6 weeks. Hoot (68) experienced difficulties with attempts to start unheated digesters in winter in Philadelphia. In Nassau County, N. Y., Sparr (142) filled new digesters with cold sludge and found that 15 days were required to raise its temperature to 90° F. with no new additions of solids. Cobb (33) reported placing primary and secondary digesters in operation without seeding, but with the addition of lime to combat the trouble caused by foaming. Other difficulties arose from excessive agitation of the primary digester contents by too frequent use of the scum jets.

Scum depths of 3 to 5 ft., suggested Mann (102), may cause loss of capacity, increased cost of operation, and damage to the structure if it blocks normal overflow. At the Ley Creek plant, where screenings and scum from the settling tanks were pumped to the digester, the tank had to be dewatered every two years for a period of nine years to remove some 4 ft. of scum. Difficulties with seeding the scum were responsible for its slow digestion. The final remedy involved incinerating about 5.2 cu. ft. of screenings and 1.5 cu. ft. of skimmings per m.g.d. of flow.

Rockecharlie (127) pointed out that many ailments of digesters which cause a drop in pH cannot be cured with lime. They are, however, difficult to pin down, and a program of liming should be initiated while a search is made for the cause of pH drop. Moderate liming can do no harm and may prevent serious foaming.

The optimum temperature for anaerobic digestion was not found by Parkes (116), although 80°, 85°, 90°, 95°, and 100° F. temperatures were used. Three tanks operated at 120° F. produced gas identical with that at other temperatures, but yielded a more filterable sludge. Schroepfer (134) calculated the annual value of heat requirements for raw waste temperatures of 60°, 80°, and 90° F. to be $5,000, $10,000, and $15,000, respectively, based on a digestion temperature of 95° F. Vilen (156) noted that the temperature of a digester is not accurately indicated by thermometers and found it more satisfactory to pump sludge a few minutes from all drawoff levels and measure the temperature of final samples. Jepson and Klein (78) experimented with the heat-pressure treatment of activated sludge by the Porteous process and found it digested at a much lower rate thereafter.

Miscellaneous operational experiences came from several authors. Sperry and Pfeiffer (144) reported a loss in gas production, which was traced to too much recirculation at the wrong time in an overloaded digester, causing the loss of too much seed to the secondary digester. Anderson (4) found supernatant with 15 per cent solids coming from a secondary digester being used as a holding tank. To relieve the excessive load thus placed on the primary clarifier, operational procedures were changed. The supernatant from the second digester was then reduced to 0.5 per cent solids. Successful operation of a digester at high rates was reported by Blodgett (18) of Columbus, Ohio. Using a catalytic reduction process, one digester is operating at 3.36 times the normal solids load.

Gas Production

Factors affecting the ratio of gases produced during the digestion of sludge are the subject of a dissertation by Alegnani (1). Sperry and Pfeiffer (144) observed a loss in gas production in raw sewage having cyanides averaging 0.2 p.p.m.; in wet primary sludge containing copper varying from 0 to 60 p.p.m.; and in a case where primary digested sludge contained 6.4 p.p.m. of chromium. Laboratory experiments by Vryburg (157) showed that gas production was reduced by one-half by 500 p.p.m. chromium, and to one-sixth by 1,000 p.p.m. chromium. A variation in gas production with digester loading is reported by Vilen (154). The plant at Kenosha, Wis., produced 11 cu. ft. of gas per pound of dry solids when the digester was operating at 45 per cent capacity. As the plant approached its design load, the gas production dropped to 6.6 cu. ft. per pound of dry solids. The addition of ground garbage to the sewage in Richmond, Ind., had the effect (129) of reducing the volatile solids from 0.61 to 0.58 lb. per cubic foot per month. At the same time the gas per cubic foot of volatile solids increased from 7.3 to 8.2 cu. ft. The importance of this is pointed out by Chase (30), who estimates that by 1965, 45 per cent of all United States homes will have garbage grinders.

Attempts to manufacture methane locally from farmyard, domestic, and industrial wastes are reported (7). Pulverized wastes are mixed with liquid and digested to produce a gas having 650 to 700 B.t.u. Lesenyei (92) published results of experiments in Hungary on the production of methane by anaerobic digestion of sludge, agricultural wastes, and garbage by both thermophilic and mesophilic organisms.

Design

On the basis of experience with gas production in digesters at Kenosha, Wis., Vilen (154) suggests that the present standards of digester design are inadequate. For resort areas Borden and Rodie (21) recommend heated digester capacities of 3 cu. ft. per capita, based on the maximum summer population, or 4 to 5 cu. ft. per capita if unheated. In South Africa, Hamlin (59) noted that the sludge capacity of digesters was a function of the dietary habits of the various segments of the population served. Capacities provided are 2.5 cu. ft. per European and 5.0 cu. ft. per non-European in the contributing population. Ross and Tolman (129) reported that the anticipated effect of garbage ground into sewers was the criterion for digester dosing capacity in Richmond, Ind. A capacity of 10 cu. ft. per capita was provided, because 0.35 lb. of garbage per capita per day is ground into the sewers. At Jasper, Ind. (6) a 60 per cent increase in all sludge handling units is provided to offset the effects of community-wide household garbage grinding.

Flood (47) discussed design trends as to covers, heating systems, scum control, and removal of sludge, super-

natant, and gas in digesters; and Rudolfs (131) pointed out the trends in digestion of sludge and wastes in the United States. Cunningham (36) discussed the design of a new plant in Portland, Ore. He believes that most plants lose digester capacity by introducing sludge too low in solids. He, therefore, provided for drawing raw sludge continuously and slowly through visible sludge spouts set to give a steady dribble of heavy sludge. Direct steam injection is used to heat the digester. Advantage is taken of the expiration of the Downes patent on floating covers. A central support, as well as the conventional peripheral support, is provided for the cover when the tank is empty. This facilitates erection and reduces stresses. The cover and gas dome were fabricated locally at appreciable saving in cost. Greene (57) reported results of three-stage digestion. It was found that most of the digestion was done in the first two tanks and that the third served largely as a concentrating tank. Wilcox (163) presented data to show the beneficial effect of sludge mixing. His results were based on the use of a draft tube mixer. Similar results were discussed by Geiger (51), who describes the use of Burkhardt's stirring and circulating device, including a special adaptation of the mechanism for the removal of material that does not digest. Proper mixing can set up optimum conditions for digestion by distributing the material, removing liquids and gases of decomposition, maintaining uniform temperature, and separating non-decomposable matter. Various references to patented digesters appeared in the literature. One patent is cited (5) for a device to agitate, degasify, and disintegrate scum by injecting sludge gas below the surface of the scum layer. Another (158) involves a heat exchanger for sludge digesters which embodies high-frequency vibrators within the pipes to prevent adhesion of sludge to the pipe walls. A unique arrangement is described by Benas (15), in which economy is obtained by central digestion of sludge produced in two separate treatment plants in San Francisco.

The possibility of utilizing reverse refrigeration to heat sludge digestion tanks was discussed by Smith and Morris (139). The heat pump is shown to be more economical than oil when electricity costs less than $0.01 per kw.-hr. Tests of sewage plants indicate that it might be advantageous in small plants where the amount of gas is negligible in comparison with the cost of utilization, or in large plants where the gas can be used to generate electricity needed in plant operation. Heat extracted from raw sewage would change its temperature less than 1° F., hence would have no adverse effect. Excess electricity can be sold. Advantages might include the lack of need for gas storage, ease of making the heating automatic, small space requirements, cleanliness of equipment, and ease of initial heating of digester after shutdown.

Sludge Disposal and Utilization

Dewatering

Keefer and Meisel (85), in laboratory experiments using the standard Büchner funnel test, showed that the addition of either raw activated or raw humus sludge to digested primary sludge materially reduced the filtration rate. Higher filtration rates were obtained with digested humus-primary sludge mixtures as compared with raw humus-digested primary sludge mixtures.

As has been repeatedly demonstrated, ferric chloride was a more effective coagulant than chlorinated copperas. If the price differential is sufficient the latter coagulant may, however, be more economical. The tests showed that adding some ferric chloride with chlorinated copperas might prove an economical procedure where

filter yields higher than those obtainable with chlorinated copperas alone are desired.

Additional laboratory tests with elutriated digested primary, activated, and humus sludge mixtures showed that conditioning these sludges with lime as well as ferric chloride materially increased the cake output. As ferric chloride is more than five times more expensive than lime, it was found more economical to use both as coagulants rather than to use ferric chloride alone. This conclusion, long established for un-elutriated digested sludges, is of interest because the tests were performed on elutriated digested sludge mixtures having a total alkalinity of only 100 p.p.m.

Benas (15) described sludge handling at the Southeast sewage treatment plant in San Francisco. Here, raw primary sludges from both the North Point and Southeast plants are digested, elutriated, vacuum filtered, and dried for use as fertilizer. An innovation is the use of single-stage elutriation between the primary and secondary digesters to reduce digested sludge alkalinity and improve secondary tank thickening. When plant effluent was substituted for city water in two-stage sludge elutriation prior to filtering, the percentage of ferric chloride required for sludge coagulation increased 1 per cent. Sludge and coagulant mixing prior to filtration is limited to about 20 sec. This is in line with the present trend. Adding the ferric chloride to the incoming sludge at the top of the mixer, with bottom discharge of the coagulated sludge, has given improved results over the former bottom chemical feed and top discharge.

A dust problem in handling the dried sludge is giving much concern and no definite solution has yet been found. Pelletizing equipment is in use to produce a more granular product, but the dies wear out rapidly. This problem also remains to be solved.

Filtration of Manchester (England) activated sludge with chlorinated copperas gave a cake moisture of 83.5 to 89.8 per cent, according to Jepson and Greene (76). The cake output averaged 0.74 lb. of dry solids per square foot per hour, with an average chlorinated copperas demand of 19.1 per cent. Filtration of elutriated digested sludge produced a cake of 72 to 75.9 per cent moisture, with an output of 1.35 to 1.72 lb. of dry solids per square foot per hour and a 13 per cent dosage of chlorinated copperas on dry basis. Chlorinated copperas proved cheaper than ferric chloride, despite the higher dosages required and the lower rates of filtration.

Heat treatment to 290° to 370° F. coagulates, breaks down the gel structure of sludges, and reduces the hydration and affinity of solids for water. Consequently, the water separates out readily by settling and dewaters in filter presses. Lumb (96) reported the 10-year results obtained with difficult sludges produced in Halifax, England, by this process. The supernatant liquor equaled 60 to 65 per cent of the volume of raw sludge. The filter cake from the presses contained 48 per cent moisture. It is stated that the separated liquor had no detectable influence on the final effluent, and the process is free from odor nuisance. The product is sold as manure. In contrast with this, Jepson and Klein (78) state that heat treatment of sludge results in liquor which is foul and contains up to 36 per cent of the original solids and 59 per cent of the original nitrogen in solution. Heat-pressure treated sludge has a deleterious effect on subsequent digestion.

Clements, Stephenson, and Regan (32) reported that sedimentation of all types of sludge is promoted by freezing. Filtration after freezing with chemicals is greatly accelerated, yielding a filter cake which is friable and contains 30 per cent solids. The chemicals must be added before freezing; alum gave the best results. As the

dosage of alum was increased from 20 to 1,000 p.p.m., the rate of filtration after freezing and thawing and the quality of cake improved progressively. Complete freezing is essential, but the method of thawing is immaterial. The supernatant liquor after thawing has oxygen demand in the order of sewage. Bruce, Clements, and Stephenson (22) reported the work done at the Northern Outfall works of London County Council during the past 3 to 4 years with sludge freezing vacuum filtration, centrifuging, and concentration of sludge.

Utilization

At Schenectady, N. Y., Ordway (114) described the facilities installed to make the digested sewage sludge available to agriculturists. The liquid digested primary sludge is dewatered by vacuum filters and heat-dried to about 10 per cent moisture. This dewatering job involves removing approximately 1,120 lb. (or 135 gal.) of water per 80-lb. bag of fertilizer produced. If all sludge is utilized, about 1,000 80-lb. bags will be produced weekly at present plant loading, or 1,300 bags per week at 1970 design rates. The product is to be called "Orgro." Fertilizer storage space has been provided during seasons of slack demand.

The Milwaukee Sewerage Commission (11) announced a contract for production of Vitamin B12 concentrate from the processed sewage sludge, called Milorganite. A pilot plant is to be built and operated with private funds. After a quantity of the vitamin is produced, the promoters are to demonstrate it to potential users as a supplement to animal and poultry feeds. The material is valuable in hastening growth of animals and poultry. If a market demand develops after one year's operation of the pilot plant, the company must then decide whether to go ahead with the construction of a full-scale $1,000,000 plant at the sewage plant site. The contract may yield the Commission several hundred thousand dollars the first year of commercial operation. About 140 kg. of pure Vitamin B12 would be secured from the 70,000 tons of Milorganite annually produced. The vitamin can be marketed, either as a 40 per cent aqueous solution, or as a dried powder.

At present, Milorganite yields a gross revenue to Milwaukee of about $2,400,000, which pays about 60 per cent of the total cost of plant operation. The proposed extraction process will not alter the value of Milorganite in any way, nor will the process perceptibly reduce the output of fertilizer. In addition to pilot-plant studies with Vitamin B12, the research organization is to conduct research and development for other possible valuable by-products in Milorganite.

Lunt (97)(98)(99) has added materially to knowledge on sludge use. In these releases an agricultural scientist presents data without bias. At the Connecticut Agricultural Experiment Station digested sludge has been rather extensively investigated for several years. The following are a few of the major conclusions from the studies:

1. Sludge supplies nitrogen to plants in abundance, and high application (in excess of, say, 75 or 100 cu. yd. per acre) may overdo a good thing and actually injure some plants.

2. Sludge readily takes care of soil deficiencies from minor elements. All of the sludges tested contained rather high amounts of copper and, especially, zinc. These metals can be highly toxic to some plants if the sludge is not used properly. Usually the injurious effects are eliminated by adequate liming.

3. Sludges need to be supplemented with 0–14–14 or 0–20–20 fertilizer.

4. Some sludges delay seed germination and allowance should be made for this possibility.

5. Sludges from different treatment plants differ in composition and in their effect upon soil and crops. They must be used accordingly.

6. Why use sludge? The answer is simple—availability and cost. Manure is decreasing in supply and getting more expensive; sludge is increasing in supply and is cheap—free for the hauling in many places.

7. Is there any evidence of real soil improvement from sludge use? The answer is yes. This is evidenced by moderate increases (3 to 23 per cent) in field moisture capacity, non-capillary porosity, and cation exchange capacity; in organic matter content up to 35 or 40 per cent; in total nitrogen up to 70 per cent, and in soil aggregation ranging from 25 to nearly 600 per cent.

Van Kleeck (153) emphasized that reports of proven sickness traceable to use of digested sludges, either vacuum filtered or air dried, continue to be negative. Likewise, experience with actual parasitic infections is negative to date. It is believed that if digested sludge used in cold climates is spread in the fall on land used for vegetables, then ploughed or harrowed under in the spring, and no more is applied to the growing crops, health hazards from pathogenic bacteria or parasitic organisms may be avoided. In a plea for greater use of sewage sludge as a soil conditioner, the author emphasized that dependence exclusively upon commercial fertilizers without consideration for the maintenance of humus content and good soil structure is an unsound practice.

Holler (67) described the progress and effect of 15 years of sewage farming in Uthleben, Germany. About 1,500 acres are used for sewage irrigation, part by spray irrigation and part by trench irrigation. Sewage is first settled in lagoons, which are cleaned once a year and part of the sludge removed is used with cattle manure in the fields. The rest of the sludge is dried on beds and composted with garbage. The importance of proper timing of irrigation is emphasized. Comparison of crop yields with non-irrigated surrounding areas is given.

Skulte (137) reviewed the nitrogen, phosphorus, potassium, lime, trace elements, humus, and water values of sewage.

Some of the constituents of humus sludge were extracted, separated, and identified by spectrophotometer by Wedgewood (161). Pyrene, fluoranthene, benzanthracine, benzpyrine, perylene, anthanthrene, chlorophylls, and carotenoids were found to be present. Some variations in different sludges were noted. The presence of chlorophyll indicates a well-treated effluent. Color in the effluents is due to products of decomposition, such as carotenoids and chlorophyll. Determination of light absorption characteristics at different wavelengths is the best method of assessing the quality of the effluent. If this value is low it indicates low organic impurities.

Mechanical Equipment

Preventive maintenance of pumping station equipment, transmission gears, ventilating equipment, clarifiers, and trickling filters is discussed by MacCrea, Smith, and Scoville (100). A comprehensive and practical preventive maintenance checklist for pumping, electrical, and mechanical units is presented by McDonald (104). Markle (103) summarizes preventive maintenance measures for electric controllers. Powers (123) furnishes information on checking the performance of compressing equipment, the distribution system, and air-powered tools and equipment to assure maximum productive capacity. Electric power system practices for sewage plants is the subject of a valuable article by Boggis and Hadley (19). The series of articles on basic factors in centrifugal pump application, and in preparing a cen-

trifugal pump inquiry, by Carter and Karrassik (28), which were reviewed in previous years have been published as a unit and should prove a valuable source reference on this subject.

A plant for recovering blast furnace dust is described by Walton (159). The plant, designed to handle a flow of 16,000 g.p.m. of washer water containing about 100 grains per gallon of flue dust, consists of two thickeners and vacuum disc-type filters. The influent enters an annular ring in the center well and flows with a rotational movement through multiple tangential diffusion ports, said to cause a circular moving, downward density current, giving balance and lateral distribution in the tank. Recirculation of previously precipitated solids to the center well is said to materially increase the settling characteristics.

Details of design and construction of plastic weir plates and a holder for use in gaging sewers are given by Sweeton (146). Ing (73) discusses the use of fiberglass plastic orifice plates in rotary distributors of trickling filters at the Dallas, Tex., plant. These plates have replaced metal plates, which had corroded. The plastic plates have proved corrosion resistant after more than two years service.

Heukelekian and Crosby (64) conducted studies on the effect protective coatings on inhibition of slime growths. Concrete test plates with and without inhibitors, and concrete plates coated with paints and without inhibitors, were submerged in open channels carrying settled sewage. Complete inhibition of growth was not attained with any of the 35 coatings and growth inhibitors tested. The accumulation of growth on all types of surfaces, with or without protective coatings, was not continuous, but is reduced intermittently by sloughing. A few of the materials tested retarded growth initially, but unless an inhibiting material completely inhibits growth, the formation of a slime coating reduces the effect of the agent.

Retipping of the standard teeth of a triturator with 55A Carboloy has given three years of service on trituration of bar screen material fed without sorting, according to Szymanski (147). Before retipping, teeth were sharpened monthly.

Setter *et al.* (35) described the Brittingham laboratory pump, in which a flexible tube is collapsed by a roller in such a manner that the fluid is displaced and forced forward. The flexible tube is rolled over a series of rollers on a rotating disc. Head discharge curves are given.

Details of design and drawings of 10-gal. table digesters and a simple gas meter are given by Sperry (143). The digesters are about 14 in. in diameter and 15 in. tall, and the gas meter slightly larger.

Detergents

Gowdy (55) presented a general discussion of the chemical structure and action of synthetic detergents. He attempted to rule out any role these compounds may play in frothing and sedimentation problems.

Flett and Hoyt (46) believe that the anionic-type detergents most commonly found in sewage would be removed to a large degree by adsorption and sedimentation. Sewage treatment problems due to loss of bacteria and frothing cannot be considered as being definitely caused by the presence of detergents.

In a discussion of the paper by Flett and Hoyt, Rudolfs (130) points out the possible harmful effects of synthetic detergents and phosphate builders on digestion, sludge dewatering, and bacteria necessary for biological treatment. He believes that frothing has been more pronounced since the advent of increased detergent sales.

Manganelli and Crosby (101) conducted a series of laboratory experiments to determine the effect of three

different types of detergents on slime growth and biological activity in activated sludge. They found that low concentrations of anionic and nonionic detergents stimulated slime growths, whereas definite retardation was caused by a cationic agent. Repeated additions of Nacconol and Ceepryn caused a decrease in the oxidizing, purifying, and nitrifying capacities of activated sludge, along with a general deterioration of its physical and biological properties. Oxidizable nonionic Tween 80 induced no detrimental effect on activated sludge or its activities. Interaction of anionic and cationic detergents diminished the inhibitive action of these materials on oxidation by activated sludge organisms.

Van Beneden (152) reported that a quarternary ammonium base in concentrations of 1 to 100 p.p.m. inhibited the growth of proteolytic and nitrifying bacteria and algae. Anionic detergents (alkyl sulfate and alkyl aryl sulfonate) inhibited the growth of nitrifying bacteria in concentrations over 50 p.p.m. and of algae in concentrations above 10 and 120 p.p.m., respectively, but had no effect on proteolytic bacteria in concentrations up to 2,000 p.p.m. Aryl polyethylene glycol had no marked effect in low concentrations on the growth of the organisms studied.

Lumb (95) added anionic and nonionic detergents in concentrations of 20 to 90 p.p.m. to sewage, which was treated in laboratory-scale trickling filters and activated sludge tanks. The results indicated that the performance of both treatment processes was adversely affected by both types of detergents. The effects of the two different detergent types were additive when a mixture was present. Either type produced a tendency for the treated effluents to froth due to incomplete decomposition of the detergents by the treatment processes. The adverse effects of detergents could be largely overcome by increased capacity of trickling filters, but activated sludge was permanently inactivated to some extent by one of the anionics tested. The effects became significant when their concentration reached about 10 p.p.m. in the settled sewage, which corresponds to about 20 p.p.m. in the raw sewage. Above that level, the effects increased sharply.

Attention has been drawn to the fact that many detergents pass unchanged through sewage treatment processes, and that their consequent presence in receiving streams may render the latter unfit for water supply (108). Methods for measuring detergent concentrations are presently inadequate to reveal the situation before trouble develops. The increasing use of synthetic detergents, plus the expansion of housing developments, give rise to concern for the future.

Isaac (75) has reviewed and summarized a number of articles (previously reviewed and abstracted in THIS JOURNAL) concerning the effect of detergents on sewage treatment and water supply. He points out that the results of laboratory-scale investigations should be applied to full-scale practice with considerable care.

Gowdy (54), after surveying a number of activated sludge plants, concluded that household detergents do not play an important role in the frothing problem. He believes that a froth-making agent is produced in the tank during oxidation. Wells (162) supports the idea of a frothing compound being manufactured by outlining several observations at the San Antonio, Tex., sewage treatment plant.

Fuhrman and Rice (50) have reported their operating experiences with detergents at Washington, D. C. A reduction in per capita B.O.D. of the sewage and in the efficiency of primary treatment units was observed. Little effect on B.O.D. and suspended solids of the primary effluent was noted. Greeley (56) discussed the basis of design of a new D. C. works allowing

operating flexibility for froth control. Berg (16) brought forth some of the complaints of the operators with regard to difficulties encountered due to detergents. He also pointed out that control of froth in sewage plants is an easy industrial foam control problem to overcome.

McNicholas (107) observed that a marked increase in froth accumulation on aeration tanks at the Clyde Park sewage works followed the introduction of detergent "Tide" in the district. Increasing the activated sludge solids from 700 p.p.m. to 2,450 p.p.m. had no effect upon the quantity of froth. A "Rainmaster" water spray machine was employed, preliminary results indicating that the froth can be successfully dispersed in this manner.

Lester and Raybould (93) presented an account of the current methods for determining anionic synthetic detergents and the difficulties involved.

Kay (80) employed Evans' modified methylene blue method for detergent estimation at the Mogden works. He found the method not completely satisfactory.

Degens *et al.* (40) have improved the methylene blue method for detergent estimation so that alkyl sulfate and alkyl aryl sulfonates can be detected in sewage. They have found that the increase in detergent concentration in Amsterdam sewage could be attributed to an increase in alkyl aryl sulfonate content. Also, the concentration of syndets in raw sewage showed diurnal fluctuations. A routine method for determination of anionic detergents in sewage is detailed in an appendix to the paper.

Degens *et al.* (39) have adapted Jones' method to determine small amounts of anionic synthetic detergents in sewage. The effects of various interfering substances were eliminated by a suitable choice of the volume of aqueous and organic phases and by the number of extractions. However, the effect of thiocyanate at concentrations greater than 5 p.p.m. could not be entirely eliminated in this way and two alternative methods of removal by chemical reaction are described. Sulfate and sulfonate detergents can be estimated separately by hydrolyzing the sulfates in boiling acid solution and measuring the detergent content before and after treatment. The detailed method given here has also been reported by the authors in THIS JOURNAL (40).

Refuse and Garbage

University of California investigators (8) reported the results of an excellent study on composting of municipal refuse on a laboratory and field scale. They point out that the factors fundamental to composting are those fundamental to any aerobic biological process: initial population of microorganisms, available nutrients, temperature, hydrogen ion concentration, moisture, and aeration. Some of the conclusions drawn from this work are: (a) microorganisms are indigenous to municipal refuse in such great numbers as to make inoculation entirely superfluous, (b) normal city refuse contains nutrients sufficient for rapid aerobic composting, (c) hydrogen ion concentration is not limiting in the composting of combined municipal refuse, (d) a maximum temperature of 73° to 75° C. is attained during the composting process—sufficient to kill pathogens and flies in all stages of development, (e) the moisture content for good composting of municipal refuse lies between 40 and 65 per cent, (f) the organisms involved in aerobic composting require relatively small amounts of oxygen which can easily be supplied by turning, (g) for rapid composting without loss of nitrogen a C/N ratio of 30 to 35 is needed.

Bartholomew and Norman (13) conducted experiments to study the influence of moisture content and initial temperature on the rate of biological heat production from decomposing oat

straw under adiabatic conditions. They found that the largest hourly increments of temperature rise occurred with initial temperature of 30° C., whereas at 20° C. the incubation period was considerably prolonged. Microbiological activity, as measured by heat production, was highest at the highest moisture content used (275 per cent). Although decomposition and heat production were less at lower moisture contents, the lesser heat capacities of the systems resulted in similar rates of temperature rise at all moisture contents studied.

The Committee on Refuse Collection and Disposal of the American Society of Civil Engineers (10) issued an extensive report on refuse problems. The phases investigated by the Task Committees included: (a) collection, (b) dumping and land fill, (c) hog feeding, (d) incineration, (e) reduction, (f) other methods of disposal and utilization of wastes, and (g) state activities.

Reclamation

In a field study conducted by the University of California (25) on waste water reclamation, the following conclusions were drawn: (a) A bacteriologically safe water can be produced from settled sewage or from final effluent if the liquid passes through at least four feet of soil; (b) a water of satisfactory chemical quality also can be produced providing high concentrations of undesirable industrial wastes are not present in the sewage initially; (c) a highly treated sewage plant effluent must be used for spreading in order to obtain high percolation rates; (d) a percolation rate of at least 0.5 acre-ft. per acre per day can be expected when spreading a final effluent on a Hanford fine sandy loam; (e) the optimum method of spreading basin operation is to spread continuously for about a month, then to allow the basin to rest until the moisture content reaches the wilting point; and (f) mosquitoes and algae may necessitate control measures.

Stone (145), in a discussion of land disposal of sewage wastes, points out that such wastes may be economically and safely disposed of to porous soils by irrigation of restricted crops or within spreading areas. Land disposal of effluents also may be used for recharging of underground aquifers with high quality, non-turbid, and fully oxidized water. Nuisance and health hazards may be controlled by adequate technical supervision. The author summarizes the design and operational factors involved in land disposal as: (a) irrigation and spreading rates with different soils, (b) surface soil conditioning, (c) cropping, (d) cycles of effluent application, (e) effluent quality, (f) climate, and other variables.

Henkel (60) summarized the satisfactory performance of the waste disposal facilities of the Du Pont Co. in Victoria, Tex. Dilute aqueous wastes are impounded and subjected to solar evaporation. Concentrated aqueous wastes are to be injected into subterranean sands through a deep well. At present, the waste brines are stored in a diked basin. Cooling waters are tested to insure suitability of their discharge into the stream. Organic liquids, waste gases, and organic solids are burned. Sanitary wastes are discharged into an Imhoff tank and the effluent is then retained in a lagoon.

Miscellaneous

Howland (70) presented calculations to estimate the effect of temperature on sewage treatment processes. He points out that the value of temperature coefficient appears to be somewhat less than 1.035 for purification in heavily loaded plants, whereas the value generally used for B.O.D. calculations is 1.047.

Allen and Smith (2) studied the removals of *B. coli* and *Strep. fecalis* by large-scale sewage works and the num-

bers of these organisms in the effluents from small domestic sewage treatment plants. They found that the highest removals in large-scale works were performed by trickling filters and humus tanks. The results from small plants indicated that *Strep. fecalis* was removed much more effectively than *B. coli*.

Jepson and Greene (77) have shown in a series of laboratory experiments that oxidized nitrogen does not become available for biological life until free dissolved oxygen has disappeared. The quality of settled sewage may be improved by the addition of nitrate-containing effluent, which can prevent the onset of putrescence.

Measurement of sewage flow using radioactive tracers was undertaken by Truesdale (151). He found that the flow of sewage through settling tanks could be traced satisfactorily by adding radioactive rubidium. The long tails of flow-through curves, which may be undetected by other means, could be determined. Preliminary experiments to trace the flow through trickling filters by means of Ru^{86} were conducted.

Rhode (128) reviewed recent developments in sewage treatment plant design in Germany with examples from various treatment works.

To maintain an efficiently operating sewer system in the metropolitan areas adjacent to Washington, D. C., a program of planned maintenance was carried out. Colony (34) emphasized that planned inspection is the most important phase, while servicing and repair are based on the results of this inspection.

Silva and Papenfuss (136) presented results of a systematic study of algae of sewage oxidation ponds. Groups, numbers, and seasonal variation of the algal flora are given. The effects of environmental factors, loading and operation of the ponds, as well as ecological considerations on the algal population, were discussed.

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RADIOACTIVITY

General

The environmental aspects of the radioactive waste problem were reviewed by Gorman (16)(17). According to Ingraham, Terrill, and Moeller (27) the atomic energy industry has been very successful in limiting radiation exposure from reactor-produced isotopes to only a relatively few people.

Fall-Out

A number of laboratories (7)(11)(12)(55) from widely scattered areas have observed an increase in the radioactivity of the air or water following atomic bomb tests. Damon and Kuroda (7) at Fayetteville, Ark., reported that the beta radioactivity of rainwater collected on June 5 was over 1,000 $\mu\mu$c. per liter, with a decay characteristic of fission products. Subsequent rain sam-

ples during a two-month period varied in radioactivity from about 15 to 500 $\mu\mu$c. per liter. There was an apparent correlation between the level of radioactivity and the origin of the prevailing air mass.

Thomas *et al.* (56) found a noticeable increase in the radioactivity of rainfall in Massachusetts. On standing, as in lakes, radioactive products decrease in concentration at a rate faster than decay. Water purification by conventional rapid sand treatment results in a further reduction of residual activity.

The extent of radioactive air and water contamination in the vicinity of the Nevada nuclear weapon tests and surrounding communities was reported by the Atomic Energy Commission (1) (2). In 8 communities surrounding the test site (2) the highest average 24-hr. concentration of airborne radioactivity during a 13-week period varied from 0.01 to 1.29 μc. per cubic meter. The 13-week exposure for these communities ranged from a maximum of 5.2 down to 2.2 roentgens. Following two of the detonations, fallout material was deposited on some portions of U. S. Highways No. 91 and 93 to such an extent that radiation levels within some vehicles were 20 mr. per hr. or more. The concentration of radioactivity in water sources near the test site varied from 1.1 to 87 $\mu\mu$c. per ml. when extrapolated to the common base of 3 days after detonation. It was also reported that the fallout from heavy rainfall in the Troy-Albany, N. Y., area on the second day after one of the detonations was 100 to 200 c. per square mile.

Permissible Levels

The permissible concentration (1) of a mixture of fission product in drinking water depends on the composition of the mixture and on the period of time over which the water is used. It was estimated that water containing 3-day-old fission product activity amounting to 5 μc. per liter could be used safely for any period of time. To determine whether the fission product content of water measured at any other time is permissible, the measurement may be extrapolated to 3 days on the basis of the fission product decay rate.

Loosemore (33) quoted the British emergency permissible level of fission product contamination in water as 60 and 10 μc. per liter at 1 and 10 days after bomb burst, respectively.

Morgan and Straub (36) presented (a) a simplified empirical formula for estimating the curies of beta activity remaining from 1 kg. of fissioned U or Pu, (b) a formula for estimating the total radiation exposure from a rapidly decreasing dose rate, and (c) a formula for computing the maximum permissible concentration (MPC) of mixed fission products in air and in water for the time interval from 30 min. to 3 years following the explosion. The MPC, in μc. per ml., of drinking water is equal to $t^{-1.2}/1{,}000$, where time, t, is given in days.

The Subcommittee on Internal Dose, National Radiation Protection Committee (39), submitted revised and new values for the maximum permissible concentrations of radioisotopes in air and water. For continuous exposure to beta emission the MPC for $Sr^{90} + Y^{90}$ is 8×10^{-7} μc. per ml. of water or 2×10^{-10} μc. per ml. of air. The MPC for radium (alpha and beta emission) in water is less by a factor of 20, whereas the permissible concentrations for all other reported isotopes are greater than the $Sr^{90} + Y^{90}$ value.

Decontamination

The radioactive contamination and decontamination properties of phenolic and polyester resins used for laboratory bench tops were tested by Lane *et al.* (32). The surfaces of resins were contaminated with P^{32}, Y^{91}, or Sr^{89} and then the surfaces were washed with acids, alkali, amyl acetate, an anionic detergent, and Versene The polyester

resin absorbed from 4 to 25 times as much activity as the phenol resin and the phenol resin was more easily decontaminated by a factor of 10 or more in most cases.

Talboys and Copp (55) determined decontamination efficiencies of hot and cold water, acids, alkali, anionic detergents, citric acid, Versene, Igepal, and other cleaners, using rubber gloves contaminated with I^{131} or P^{32}. An anionic detergent and Versene were consistently the most effective decontaminating agents.

Contamination and decontamination of various kinds of pipe were studied (54). The retention of I^{131}, Sr^{89}, or P^{32} by the pipe amounted to 15 to 25 per cent. Roughly one-third of the retained activity could be flushed free with hot water. Nitric acid was very effective in removing residual Sr^{89} from plumbing, and citrate at high pH was effective in removing P^{32}.

Skow *et al.* (50) reported on the difficulties of decontaminating buildings and personnel following an accidental spill of 40.3 mg. of radium sulfate which was not discovered until 16 hr. after the incident.

Water and Sewage Treatment

The Oak Ridge National Laboratory staff on waste disposal (37) reported preliminary studies on the removal from tap water of Ba^{140}, Cr^{51}, Sr^{89}, Y^{91}, Sc^{46} (all in chloride form in weak HCl), and W^{185} as an anion. Each isotope was studied at three levels of activity (20,000, 2,000, and 200 counts per min. per ml. Methods of removal consisted of (a) coagulation by using three dosages each (1, 2, and 6 grains per gallon) of $FeSo_4$, $FeCl_3$, and alum; (b) take-up on natural clays; (c) removal by water softening procedures; (d) removal by phosphate coagulation; and (e) removal by various materials in small glass columns. The results are summarized in a table along with previous findings. Studies were reported by ORNL (53) on the removal of carrier-free I^{131} and Sr^{89} by anion and cation exchange resins. Up to the "break-through" at about 10,000 gal. of water per cubic foot of resin, the removal of Sr^{89} was more than 99.84 per cent with cation resins on the hydrogen or sodium cycle. Up to the "break-through," at about 2,000 gal. per cu. ft., the removal of a mixture of I^{131} and Sr^{89} was more than 99.97 per cent with a two column exchanger consisting of one volume of cation and two volumes of anion resin. Coagulation studies reported by Lacy (31) included six isotopes (and daughters) and a young and an old solution of mixed fission products. The Oak Ridge tap water, contaminated to 17,000 to 100,000 d.p.m., was coagulated with filter alum or ferric chloride and ground limestone at a pH of 6.3 to 10.0. For optimum coagulation using $FeCl_3$ and limestone the removal was more than 98 per cent for Ce^{141}, Ce^{144} (Pr^{144}), and Zr^{95} (Nb^{95}), about 70 per cent for Ba^{140} (La^{140}), and 50 to 60 per cent for mixed fission product.

Lauderdale (30) reported that, of a number of metal powders slurried with water contaminated with Ru^{106}, iron and zinc metals (500 p.p.m.) were most promising for removing this isotope. Sr^{89} was removed (more than 99 per cent) by treatment with 25 p.p.m. of lime and carbonation to pH 8.9 to 10.5 in the presence of 1,000 p.p.m. of powdered limestone.

Nesbitt *et al.* (40) studied the removal of Sr^{90} from distilled and synthetic surface waters by excess phosphate coagulation at high pH (optimum of 10.2). In a 30-min. coagulation and 2-hr. settling period, 90 per cent of the Sr^{90} in distilled water was removed with 140 to 500 p.p.m. Na_3PO_4 plus 50 to 100 p.p.m. lime. The excess phosphate was readily removed by subsequent $FeCl_3$ coagulation, with simultaneous removal of about 80 per cent of the residual radioactivity.

Eden *et al.* (10) reported experi-

ments on the removal of I^{131} in conventional water treatment processes with and without a silver salt.

Studies on the adsorptive capacity of subsoil from Arco, Idaho, for radioactivity were reported by Stewart (52). Soil was shaken for 1 hr. with reactor waste solution. The mixture was then centrifuged and the radioactivity of the centrifugate determined. Sandy subsoil adsorbed 0 to 9 per cent (comparable to the sandy subsoil from the Hanford area), whereas clays adsorbed 10 to 24 per cent of the activity.

Belcher (4) described experiments on the fate of Na^{24}, P^{32}, Co^{60}, Br^{82}, and I^{131} during sewage treatment by primary sedimentation, trickling filter, and activated sludge. At equilibrium conditions primary sedimentation resulted in a small (less than 5 per cent) removal of any of these isotopes; activated sludge and trickling filter treatment resulted in a small (less than 20 per cent) removal of I^{131}, Br^{82}, and Na^{24}, but larger removal (77 to 88 per cent) of P^{32} and Co^{60}. A concentration of 100 μc. per liter of P^{32} failed to cause any measurable radiation effects on the operation of trickling filters.

Laboratory experimentation with the activated sludge process for treating a mixture of 15 per cent radioactive (Pu) laundry wastes and 85 per cent sewage was reported by Reading *et al.* (44). Using a theoretical aeration period of about 33 hr., the removal of Pu with filtration averaged about 88 per cent with an average aerator suspended solids of 3,000 p.p.m., and 95 per cent with an average aerator suspended solids of 1,600 p.p.m. In the absence of synthetic organic detergents, frothing troubles were not experienced, the B.O.D. removal was excellent, and sludge settleability was very satisfactory.

The biological oxidation of complex synthetic laundry wastes containing radioactive isotopes and the uptake of isotopes in biological slimes and sludges were investigated by Gloyna and Geyer (14). The cleaning compounds Versene and Igepal in concentrations less than 125 p.p.m. had little effect on slime growths formed on rotary tubes used to simulate a trickling filter. Citrates were readily utilized by the slimes. Removals of 45 per cent for Ce^{144}, 20 per cent for P^{32}, and a lesser amount for Sr^{89}, Ru^{106}, I^{131}, and Cs^{134} were obtained. Substantially greater removals were obtained by aeration of activated sludge in bottles. The factors controlling removal were discussed.

Following pilot-plant studies at Los Alamos, a conventional trickling filter plant is being built at the National Reactor Testing Station near Idaho Falls, to handle simultaneously both domestic sewage and radioactive laundry wastes (5). The design includes recirculation and special features of control and flexibility to permit studying the best mode of operation.

Dobbins *et al.* (8) reviewed the objectives of a study underway on the treatment of synthetic laundry waste by a pilot-plant trickling filter.

Carter (6) studied the removal of radioactive iodine in weak sewage by laboratory trickling filter columns. The high removal of 76 to 92 per cent for dosage rates of 6 to 2 m.g.a.d., respectively, on filters 6 ft. deep probably can be explained as initial removals from intermittent batch feeding of carrier-free I^{131}.

Biological treatment has limited application to the removal of radioactivity, according to Ruchhoft and Setter (48). This is particularly true of soluble ions, such as I^{131}, or ions, such as P^{32}, which may be metabolized but are isotopically diluted by the nonradioactive phosphorus in sewage. However, radioactives, such as Pu, which tend to form insoluble complexes, are readily absorbed on biological floc. Biological treatment of certain wastes may be effective as an adjunct to chemical treatment by removing, through oxidative assimila-

tion, the interfering organic sequestering constituents.

Disposal and Incineration

A patent was granted to Ginell (13) for a process of adsorbing radioactive cations on montmorillonite clays and irreversibly fixing the cations on the clay by heat treatment at 750° to 1100° C. so that the mineral could be safely disposed of by land or sea burial. The favorable features of the process were discussed by Hatch (20)(21).

Cost analyses of methods of disposal for wastes of high-level contamination (20 c. per liter) were made by Herrington *et al.* (23). The methods considered were (a) pumping high-level wastes into "dry" oil wells 1,000 to 10,000 ft. below the surface of the ground, (b) fusion of wastes into glass that could be buried at a local site; incorporation of concentrated liquid wastes into a concrete monolith for, (c) burial in areas of low rainfall, (d) burial in the depths of oceans, or (e) burial at local sites after soluble activity has been removed by a leaching process. Fusion with clays or sulfur, coprecipitation (such as with aluminum hydroxide), and electrolytic deposition were not considered suitable methods for high-level waste. The optimum method varies with plant location and techniques, which need further detailed study.

Hatch (22) is of the opinion that current economic evaluations of waste disposal are somewhat premature because the problem of "permanency" of disposal has not been fully investigated.

Hirsch (24) reported that the highly radioactive fission product wastes at Hanford are concentrated in a batch-type, stainless steel, pot evaporator at a rate of 500 g.p.h. One pass reduces the volume of heel to 30 per cent of the original volume. Foaming is controlled with a silicone compound. Incrustation is controlled by limiting the volume reduction to 30 per cent and by periodic cleaning with 60 per cent nitric acid. The condensate, which has been decontaminated by a factor of 10 for alpha and 10,000 for beta activity, is disposed of by cribbing. Reduction of the volume of waste to be stored represents a major saving, since storage is estimated to cost $0.37 per gallon.

Powell and Andrews (41) described a safe and comparatively simple method of radioactive waste disposal used by the National Institutes of Health. Contaminated refuse or equipment and liquid wastes are placed in child-size, concrete burial vaults. The vaults are filled to within 3 or 4 in. of the top, then filled flush with high-slump concrete. Ultimate disposal may be by dumping at sea in depths of at least 1,000 fathoms of water. Land burial of the sealed vaults is considered a possibility, since leakage of contents to surrounding earth and water is minimized and removal is facilitated if a new burial site must be used.

Three reports (19)(28)(29) dealt with the disposal of solid wastes by incineration.

Radiation Effects

Manitowitz (34) discussed the design parameters of large-scale gamma irradiators and the potential and cost of radiation power for causing polymerization reactions.

Dunn (9) reviewed pertinent studies on the germicidal action of high-voltage X-rays and cathode rays and beta-gamma radiation from Co^{60} sources. The laboratory experiments indicated that terminal disinfection of water and sewage by means of irradiation with kilocurie Co^{60} sources was of no practical importance in the foreseeable future.

Experiments reported by Grune (18) indicated that 10 mc. of P^{32} and 0.1 to 10 mc. of I^{131} per liter affected the B.O.D. test by changing the rate of oxygen utilization and nitrification. However, the experimental variations

appear insignificant and were not confirmed by subsequent studies by Skrinde and Sawyer (51). The latter investigators exposed natural sewage, synthetic sewage, and sewage dilutions in Warburg respirometers to P^{32} in concentrations of 10 to 80 mc. per liter. No significant effect on biological oxidation was observed up to an applied concentration of 50 mc. per liter. In the presence of 60 to 80 mc. per liter of P^{32} a noticeable inhibition of oxygen absorption was observed in full-strength sewage, but not in dilute sewage.

Natural Radioactivity

According to Damon and Kuroda (7), the background radioactivity of rainfall at Fayetteville, Ark., in curies per liter, was for radon, $< 10^{-11}$; for radium B and C, 10^{-9} to 10^{-7}; for radium D, 10^{-13} to 10^{-12}; for radium, 10^{-12}; for thorium B, 10^{-13} to 10^{-10}; and for tritium, 10^{-11} to 10^{-12}.

The radium content of raw and finished water from single samples of 33 municipalities in the U. S. was reported by Hursh and Gates (25). The values varied from 0 to 18.7×10^{-13} g. per liter. The radium content of finished water was usually less than raw water and sometimes less by a factor of 20 or more.

New determinations by Rona and Urry (46) of the radium content of open ocean waters were reported to be 0.07 to 0.58×10^{-13} g. per liter. These results corroborate previous results for samples obtained close to land.

Analytical Methods and Instrumentation

Umemote (58) separated and concentrated radium B by means of a dithizone (in CCl_4) extraction with subsequent counting of the beta ray activity. Rodden (45) gave a rather extensive review (79 references) of the various methods that have been proposed for the determination of uranium.

Pressly and Rupp (42) presented a modified procedure for separating the rare earth elements, utilizing ion exchange resins and elution by 6N HCl and citrate solutions.

A technique for determining low levels of alpha and beta radioactivity in surface and ground waters and in fresh-water biota was described by Nader, Setter, and Goldin (38). Radioactive particulate matter in water is removed by filtration and assayed separately. The filtrate (200 to 1,000 ml.) is evaporated directly in dishes and counted in an internal proportional counter at both the alpha plateau and the beta plateau. Biota are digested with nitric acid and hydrogen peroxide. Residual solids are then deposited on counting dishes and counted similarly to the water samples. The minimum detectable activity in water by the technique is in the order of 10 $\mu\mu$c. per liter for beta and 1.5 $\mu\mu$c. per liter for alpha radiation (15).

Setter, Nader, and Hagee (49) presented studies on the characteristics of an end-window counting set and concluded that these counters have limited usefulness for assaying the beta radioactivity at levels in the order of the maximum permissible level of unknown isotopes in drinking water (39). Upson (59) reported on an experimental method applied to end-window G-M tubes which can be used to obtain an approximation of the absolute beta activity. The method is useful for correlating the results of different G-M tube counters.

A continuous-flow radiation monitor and a calibration unit were developed by Hurst (26) primarily for detecting contamination in drinking water. The monitor, designed for measuring alpha-beta-gamma activity, is claimed to detect Sr^{89} at a level of 3×10^{-6} μc. per ml.

Monitoring methods used to determine whether foods were suitable for consumption after damage by blast, fire, water, or contamination with

radioactive materials were described by Rankin (43).

Loosemore (33) designed and described a low-voltage G-M counter for measuring water contamination in the range 0.5 to 500 μc. per liter. A solid source calibration jig obviates the need of liquid standards.

Rosenthal (47) described an apparatus used in routine monitoring of water supplies for radioactivity. A stable, convenient system for counting radon was described by Bate, Volchok, and Kulp (3). The lower limit of measurement is the amount of radon in equilibrium with about 10^{-14} g. of radium. Stainless steel ionization chambers operated at 300 v. in conjunction with a vibrating reed electrometer were used. The radon from liquid samples is swept into the evacuated chamber by means of nitrogen gas.

Nonequilibrium conditions between radon and its daughters was found in uranium mine atmospheres by Tsivoglou, Ayer, and Holaday (57). From an analysis of radon-daughter decay curves, the concentration of the daughters could be assayed and the effectiveness of ventilation in protecting mine workers may be more accurately evaluated.

Studies by Miller and Leboeuf (35) on a Simpson proportional alpha counter indicated that beta backgrounds of 3×10^7 d.p.m. reduce the observed alpha counting rate by 0.5 per cent. This reduction increases to 2 per cent for backgrounds of 4×10^8 d.p.m.

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The second and concluding section of the "1953 Literature Review," covering references to industrial wastes and stream pollution, will be published in the June, 1954, issue of THIS JOURNAL.

NON-MEMBER MEETINGS OF INTEREST

The 1954 Southern Industrial Wastes Conference will be held at the Shamrock Hotel, Houston, Tex., April 21–23, 1954. The conference, expected to be the largest conference of its kind in the South, is jointly sponsored by the Southern Association of Science and Industry, the Texas Chemical Council, and the Manufacturing Chemists' Association.

A one-day conference on Instrumentation in Water, Sewage, and Industrial Waste Treatment, to be held April 20, 1954, at Manhattan College, New York, N. Y., is planned to bring together both makers and users of instruments for water purification and waste treatment. Additional information may be obtained from: Civil Engineering Dept., Manhattan College, New York 71, N. Y.

The Fourth Inter-American Conference of Sanitary Engineering, organized by the Inter-American Association of Sanitary Engineering, will be held July 25–31, 1954, at São Paulo, Brazil. Detailed information may be secured by contacting the General Secretariat, Fourth Inter-American Conference of Sanitary Engineering, Postal Box 8099, São Paulo, Brazil.

Sewage Works

SEWERAGE PLANNING FOR METROPOLITAN FRINGE AREAS *

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This paper presents general, engineering, and financing considerations peculiar to providing sewerage service in metropolitan fringe areas, which are, of course, more or less developed sections bordering the outer rim of the metropolitan center with which they have common social and economic interests.

There are some 168 metropolitan areas in the United States surrounded by communities in the "fringe" classification. Richmond, Va., for example, has an area of 24,000 acres within the city limits. Its metropolitan area, however, which is considered likely to require sewerage service within the next 50 years, comprises nearly 47,000 acres. In planning intercepting sewers and treatment facilities for the city an area totaling about 280,000 acres was actually considered with respect to probable future development and sewerage needs. The District of Columbia, particularly, offers a striking illustration of a metropolitan center bordered by numerous and extensive fringe areas in all directions (Figure 1).

Fringe areas are likely to increase in number and extent as new decentralized cities become a reality. Thus, a recent report of the Metropolitan Planning Commission of Atlanta, Ga., stated: "Crowded, congested cities could be on their way out. In their place we could have a new type of city in the future—wide, green, open, and well planned. Its people would be on wheels and wings, moving swiftly and surely from suburb to suburb, from rim to core and back again." Even at present, Americans are rapidly changing into a nation of suburbanites. Since 1947, the total population of the nation has increased by 15,000,000, but population of what loosely may be called "the suburbs" has increased by something like 17,000,000.

In this paper reference is made to the current planning of sewerage facilities for Fairfax County, Va., a 400-sq. mi. fringe area of the Washington metropolitan district, and to Arlington County, Va., which is located across the Potomac from the District of Columbia and which separates Fairfax County from the nation's capital. The development of sewerage programs for these areas is typical of the problems encountered in sewerage planning for metropolitan fringe areas. The evolution in a 20-year period of Arlington County from a "fringe area" confronted with sewerage planning to a metropolitan area with fully operating and extensive sewerage installations illustrates further principles pertinent to the subject of this paper.

General Considerations

Fringe areas may be expected to have populations of 125 to 150 or more

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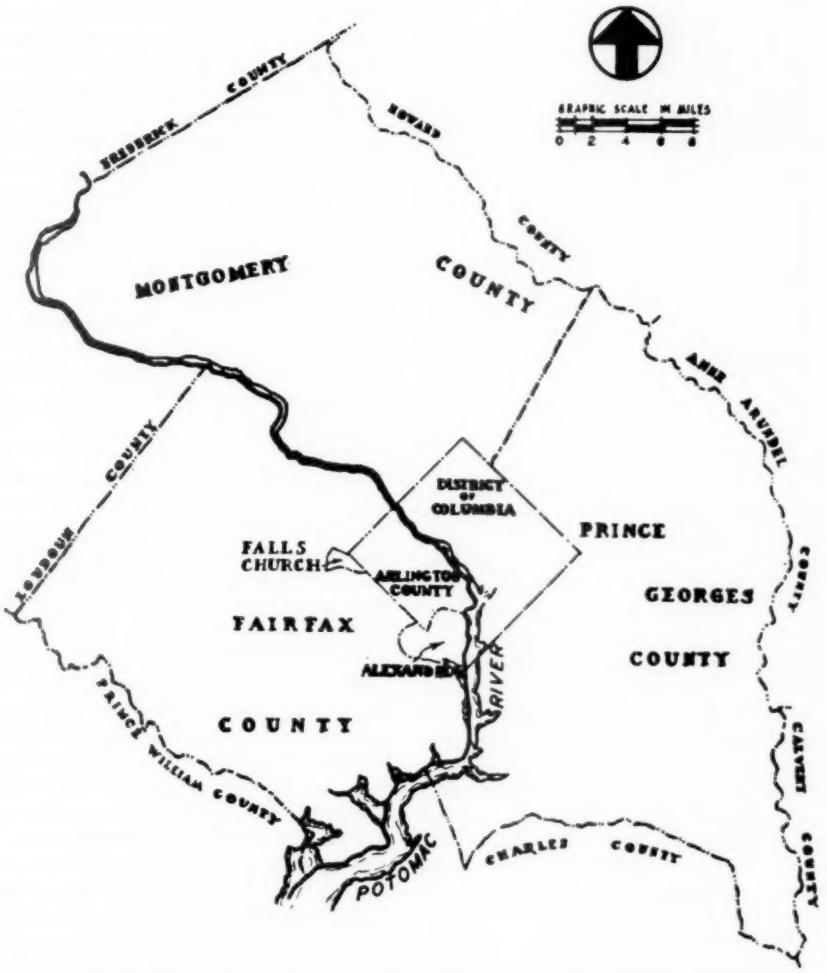

FIGURE 1.—Fringe areas in the Washington, D. C., metropolitan district.

persons per square mile when demands for public sewers begin. Generally, they are growing areas as to population and may be expected to increase in size geographically and in importance with passing decades. These factors are related chiefly to the activities of the metropolitan area for which they frequently serve as dormitories. Sometimes, as in the case of Arlington County, Va., their transition from "fringe" to "suburban" to "urban" to "metropolitan" may take place in giant steps. In 1935, the population of Arlington County was 35,000, of which less than 10 per cent were then served by sewers. Today the county population is 155,000. It has 360 mi. of sanitary sewers and a 20-m.g.d. sewage treatment plant, serving about 93 per cent of its population.

When Are Sewers Needed?

The most impelling motive behind the demands for sewerage service in fringe areas is the failure of other methods of sewage disposal. Fringe New York City areas on Long Island were not served by public sewers for many years, notwithstanding substantial population development, because individual septic tanks and cesspools operated exceptionally well in the sandy soil formation found there. On the other hand, in somewhat sparsely populated areas in Fairfax County, with densities of 2 to 3 persons per acre, public demand for sewers is great because existing septic tank systems do not operate satisfactorily in the tight, clayey soil. On this account, local authorities refuse to issue permits for new installations on lands previously subdivided for building purposes. They also find it necessary to deny approval for new subdivisions of land for buildng purposes in areas for which septic tank installations are contemplated. Incidentally, this has a depressing effect on the taxable base of the county because large properties cannot be subdivided into higher bracket taxable parcels and houses with faulty septic tank systems have a reduced market value.

Engineering Considerations

Comprehensive Planning

Generally, fringe areas have their own little centers of population, either commercial or residential, where more than average population density brings about a demand for sewerage facilities. Such demands are frequently filled by the real estate entrepreneur in connection with his original development. However, even though the ultimate execution of a sewerage plan may initially provide facilities only for such areas, piecemeal decisions based largely on the pressures of the moment should be avoided.

A fringe area is not likely to be a public body politic and corporate although, of course, it may constitute a segment of a larger political subdivision of the state. In order to provide legal, financial, and administrative means, therefore, for effecting the desired relief in these areas, in a comprehensive manner, the creation of political entities endowed with power to incur debt, to collect charges for service, with rights of eminent domain, and with similar basic authority is required. This may necessitate the creation of improvement or sanitary districts, or sewerage authorities, or entail possible annexation by the adjoining municipality. The formation of such corporate bodies should be predicated, where possible, on a drainage area basis, for which planning of facilities and their subsequent construction by stages may proceed according to a master drainage plan and according to ability to finance.

Use of Metropolitan Facilities

In many instances, particularly in connection with intercepting and outfall sewers and sewage treatment, use of the existing facilities or planning for joint use of proposed facilities of the urban or metropolitan neighbor in border areas warrants investigation.

As an illustration of this, it was possible in the case of Fairfax County to plan jointly with the city of Alexandria for the combined use of a proposed trunk sewer and treatment facilities to serve a portion of the adjacent county area. By such joint use and lease arrangement, a saving of $2,400,000 by the county and city in initial construction cost on a $10,000,000 project was indicated, together with savings in operating costs totaling nearly $1,500,000 as estimated for the first 19 years. Legal problems in such partial joint enterprises may present sizeable obstacles, frequently necessitating special legislation. When substantial cost reductions are indicated, however, the efforts necessary to over-

come legal obstacles are fully warranted.

Extending the facilities of the metropolitan center to serve its adjacent communities may loom as an attractive possibility, but in large areas this entails substantial engineering, economic, and political considerations. The Washington metropolitan area illustrates this situation. Following considerable general talk, the communities involved finally undertook a detailed engineering investigation to determine the economic wisdom of providing sewage treatment service for Arlington, Fairfax, Alexandria, and Falls Church at the District of Columbia treatment works. The engineering findings in this particular instance were unfavorable to this procedure. Nevertheless, they disclosed other desirable combinations at border locations for the various jurisdictions. On the other hand, advantages of treating sewage from portions of Prince Georges and Montgomery Counties in Maryland at the District of Columbia plant were apparently so striking that these fringe areas of Washington plan to discontinue operating their relatively new treatment facilities and convey the sewage from the Anacostia River watershed to the District plant for treatment.

Considerable impetus to advancing the development of sewerage facilities in fringe areas can be provided at relatively little additional investment by the adjoining metropolitan community. This is particularly true in cases where the metropolitan area is in the process of planning basic trunk and intercepting sewers and treatment works. Richmond, Va., is an illustration of this case. Initially, only a small portion of areas outside the city—that is, fringe areas—are to be developed and be tributary to the city system. Ultimately, by legal annexation or due to requirements of natural drainage, or because of agreements with outside private owners, sanitary districts, and other jurisdictions, a considerable portion of the outside area sewage will become tributary. Initial intercepting sewer capacity is, therefore, being made adequate to include the outside areas at a time when this can be accomplished at small additional cost. Treatment capacity, of course, may readily be increased in the future as needed. Arlington County, too, makes a practice of permitting communities outside its borders but within its natural drainage area to discharge to the county's sewerage facilities and in certain instances provides the necessary additional capacity through a rental arrangement.

Population

Estimates of population growth and its distribution to the areas under study are basic to the determination of capacities and rate schedule requirements in sewerage programs. The latter are especially important where bond issues are supported solely by use charges. The development of such estimates is more difficult in fringe areas than in developed urban areas because of undefined growth trends and uncertain direction of development. In this connection, mere availability of space (or in other words, determination of future growth in fringe areas on the basis of population density units) is not a reliable factor in determining population totals or population distribution. Source of population, rather than density, is the basic consideration. Therefore, factors influencing growth and population movements of the metropolitan center must be evaluated in estimating fringe area development.

In planning sewerage facilities it may be found desirable to use two separate types of population forecasts: first, a forecast for trunk, intercepting, and outfall sewer planning—that is, a "planning population estimate"; and second, a forecast for determining rate structure and revenues to support the debt service and operating and maintenance costs of the proposed fa-

cility—that is, a "customer-load estimate." Much of the fringe area tributary to various trunk lines is not subdivided at the time sewerage planning is undertaken and only a small part of the ultimate street system may then be established. Accordingly, for sewer planning purposes, tributary population should be based on drainage areas and density estimates for the terminal year of the planning period. Density estimates, on the other hand, are determined on a judgment basis for the respective areas involved, giving due consideration to present development, known plans for future development, area features, land use, availability of other public utilities, and similar factors. Customer-load estimates, however, should be derived strictly from over-all growth considerations, the greatest weight being given to source of population, as previously noted.

Sewage Treatment

The problem of a fringe area is largely one of sewage collection rather than sewage treatment. However, this is not to imply that sewage treatment, although it may represent the minor part of the cost, can be neglected. At Fairfax, of $20,000,000 involved in the initial county-wide sewage plan $5,000,000 (that is, 25 per cent) represents sewage treatment facilities. In Arlington, the sewage treatment plant constructed during the first-stage sewerage program represented 10 per cent of the total cost. In both instances, however, sewage treatment requirements had a major influence on the sewage collection plan, both as to design and cost.

Looking back 30 to 50 years, fringe areas in the Northern New Jersey metropolitan district, probably typical of similar cases elsewhere, passed through a cycle not too different from current experiences. About 1,000 mi. of collecting sewers were constructed in a 45-sq. mi. area in the Elizabeth and Rahway River valleys before sewage treatment for this area required or received consideration. Not until the area actually became more a part of the metropolitan region was sewage treatment a factor. There is this distinguishing difference between that period and the present with respect to sewerage planning for fringe areas: today, by reason of public abhorrence of stream pollution and because of legal compulsion, sewerage planning cannot ignore or defer treatment facilities as a part of the initial program. As a result, sewerage planning in fringe areas must be on a broader base than before, particularly with respect to intercepting or trunk sewer installations and pumping and treatment plant locations. This may mean that larger areas must be encompassed by the master plan, frequently at some initial increase in cost in order to thereby achieve maximum over-all economy for the complete project.

Design Considerations

Design procedures with regard to sewers and treatment plants for fringe areas are essentially similar to design of such facilities elsewhere. They must, of course, be based on standards that have evolved from sound engineering principles as well as from practical experience with previously built works. It is not necessary to make detailed reference to these principles in this paper, with the possible exception of the determination of the ratio of peak to average flows for trunk sewer and interceptor design. In practice, much variation is found in this element of sewer design and the subject offers an interesting and useful field of study. A determination of these ratios in relation to various average flow rates must be made in the early design stage, taking into account all conditions bearing thereon, including pipe materials, joint construction, foundations, cradling practice, ground-water conditions, and frequency and extent of permis-

sible overflows. Figure 2, illustrating the ratios adopted for the Fairfax design, is of interest in this connection.

Financing Considerations

How Far Should Sewers Be Provided Initially?

Probably the most difficult question facing the engineer-planner and the policy-making body in connection with fringe area sewerage is how far into the area sewers should be provided initially. There are exerted the usual pressures from home owners remotely located but experiencing sewage disposal difficulties, and from real estate developers seeking sewage outlets for areas they control. In addition, there are public health considerations. Although it is desirable to take these and similar factors into account, the final determination must frequently be made chiefly on a basis of "Will it pay?" In this connection, the requirements of the bond buyers and the temperament of the bond market exert the greatest single influence. Built-up sections of rural centers will naturally be able to pay their way. Obviously, as sewer lines are extended to the less densely populated areas, the returns in relation to the cost, or what may be termed the "revenue-to-cost ratio" becomes diluted. Financing the project through the sale of revenue bonds is possible only to the point that the bankers may consider such dilution safe.

All new facilities serving an area are in a sense "generators." A new tunnel, bridge or highway will generate traffic. A natural gas-line, a water system, or a sewer system will bring new buildings. Therefore, in weighing the factors of how much debt the system can stand, the hoped for addi-

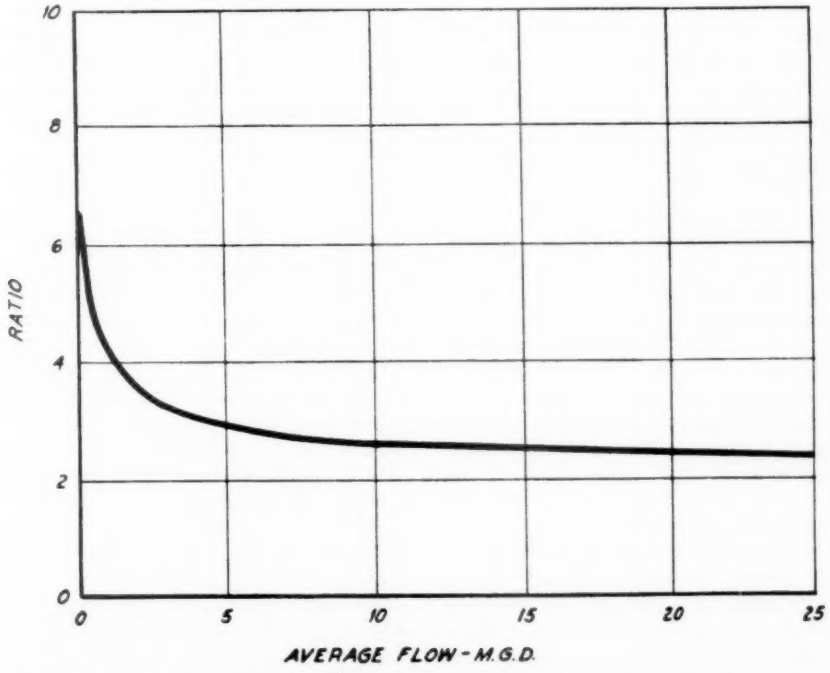

FIGURE 2.—Ratio of design rate to average sewage flow in trunk sewers of new collecting systems, Fairfax County, Va.

tions, as well as the initial connections, should be properly projected. However, sewer rates must be reasonable and no undue burden should be placed upon the initial customers. Particularly, in revenue supported bond issues, vacant land cannot easily be charged for benefits. Accordingly, the determination of the limits of the area to be sewered involves principally a financial analysis based upon a determination of costs, and immediate and potential revenues for a series of trial areas of varying extent.

In considering the Fairfax County system, for example, the extent of areas to be sewered was studied on the basis of three groups classified as 1st, 2nd, and 3rd priority groups. To maintain what was locally considered a reasonable rate schedule in connection with sewerage for all priority groups, provided insufficient coverage in the opinion of the financial advisers.

"Coverage," as here used, is the ratio of net earnings after all expenses to total debt service, meaning principal and interest. By initially serving the first priority group only, capital costs were reduced proportionately more than the number of available customers and coverage was thus increased to an acceptable ratio. In proceeding by stages, where revenue financing is involved, it is necessary that the part financed in the first instance should be able to stand on its own feet and be completely self-supporting. Further sales of bonds to finance the remaining stages can be scheduled as required, provided, however, that adequate earnings will be available for the issuance of additional bonds in order that the original bond issue may remain fully protected.

Generally, the smaller the issue and the lower the number of connections, the higher are the safety factors or coverage requirements. For instance, a system with 5,000 or more sewer connections should show 1¼ to 1½ times debt service coverage to satisfy investment requisites. The smaller communities may need a coverage of 1¾, 2, or even greater to successfully market bonds.

Future Extensions

In most instances of fringe area sewerage planning, extensions of the initial system are to be expected if the future population as used for revenue estimating is to be served. Many extensions of this type may be made by private real estate developers; the governmental unit providing trunk, interceptor, and treatment facilities only. The Arlington County experience (Figure 3) indicates that after completion of the initial program in 1936, in which 100 mi. of sewers were constructed by the county (that is, 25 mi. of trunk sewers and 75 mi. of collecting sewers), 253 mi. of sewers have since been added. These additional sewers have largely been collecting lines. Of this added mileage, 125 mi., or about 50 per cent, were constructed by private developers. Under the terms of the permit granted to the developers, these sewers become county property within 90 days following completion and approval by the county.

In setting up fringe area sewerage programs it is necessary to include estimates for trunk sewer extensions for a period in the future, corresponding to that for which the general plan is made and to allow, from operating revenues, funds for constructing such facilities, as well as certain collecting sewers not likely to be provided by private developers or financed through direct assessment. The determination of how much to set aside is, of course, at best a conjecture. Local experience is about the best guide.

Frequently, however, future extensions are needed before sufficient operating reserves for this purpose have been accumulated. Nor can all extensions and improvements be financed on a pay-as-you-go basis. A rapid growth or boom development could necessitate an additional bond issue. It is important, therefore, that the initial

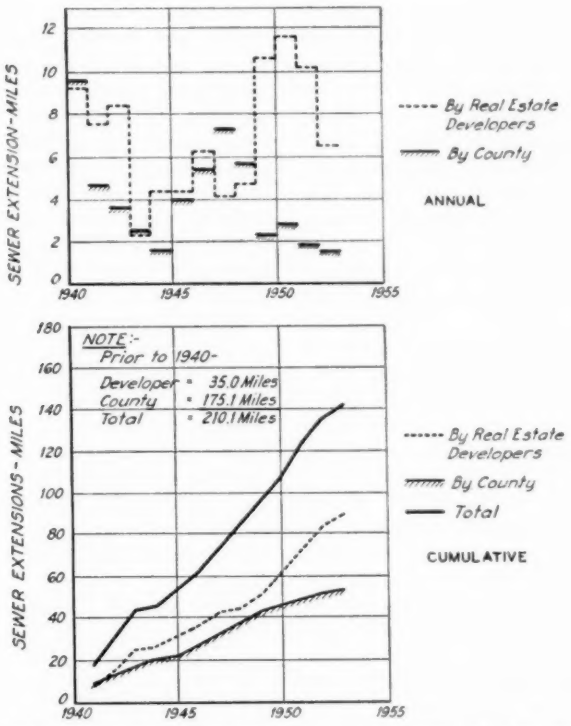

FIGURE 3.—Private vs. public construction of sewer extensions in Arlington County, Va., following installation of public county-wide system (1936).

bond issue contain proper provisions for additional bond issuance for expansion of the system. Too often restrictions are placed in bond indentures governing added indebtedness. Initial bond issues are made first liens on not only the system, but also on all extensions and improvements.

This kind of a situation can be handled by proper permissive provisions for additional financing. As previously noted, the chief concern of the investors is to safeguard their investment. Yet, extensions of a system can be profitable and wise. If the engineer's presentation of the needs, costs, and supporting revenues indicates as high a degree of coverage of the additional bonds as the original financing revealed, it will make clear the propriety of such a move, for this would indicate that present earnings will not be diluted by virtue of the additional debt. All bonds would, therefore, be on an equal lien basis.

Summary and Conclusions

In conclusion, the basic considerations presented in this paper are summarized as follows:

1. Fringe areas surrounding metropolitan centers are increasing in extent and in population because of a growing trend toward decentralization of cities.

2. Failure of soil disposal methods gives rise to demands for public sewerage systems in fringe areas, even during their sparsely populated period.

3. Formation of the body corporate and politic and subsequent planning of facilities should be on a drainage area basis, although execution of the

sewerage plan may take place by small stages as financing permits. Piecemeal decisions based on pressures of the moment should be avoided.

4. Closeness of the fringe area to the metropolitan area, which is likely to be provided with adequate sewerage facilities, presents possibilities, particularly at border locations or in common drainage areas, for the use at a minimum of cost of the trunk, intercepting, and treatment works of the metropolitan center.

5. Metropolitan centers, when planning trunk sewer and treatment facilities, should consider, where possible, fringe area needs from the viewpoint of future annexation of or contractual arrangement with such areas.

6. Estimates of population growth and its distribution are difficult in fringe area sewerage planning because of undefined trends. Separate forecasts for planning purposes and for revenue estimating are frequently warranted.

7. Sewerage planning in fringe areas cannot defer the question of sewage treatment but must provide for these facilities in the initial stages.

8. Design procedures in fringe area sewerage practice are similar to those adopted for like facilities elsewhere. An aid to such planning would be provided by the development of more data regarding ratios of peak to average sewage flows for various conditions likely to be encountered.

9. The determination of how far sewers are to be extended into the fringe area must frequently be made principally on the basis of a financial analysis. This analysis involves a determination of costs and of immediate and potential revenues for a series of trial areas. The limits are generally fixed at that point where coverage—that is "revenue-to-cost" ratio—is the least that bankers will buy at acceptable interest rates.

10. This procedure may also be adapted to determinations of extent of sewers to be provided where financing is by means of direct assessment on a frontage or equivalent basis. In such cases, in lieu of the coverage factor, the "reasonableness" of the assessment rate (that is, the ratio of the total cost of the extension to the resulting total front feet assessable) is the controlling factor.

11. Financial planning should provide for setting aside funds from revenues for future extensions of the system. In this connection, consideration should be given to the likely extensions that will be made by real estate developers. It is best, however, that the initial bond issue contain provisions for additional bond issuance, subject, of course, to an adequate earnings test. This is necessary to make possible desirable extensions in the event sufficient reserves have not been accumulated and direct assessment is not practicable.

DISCUSSION

By Charles R. Velzy

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Some of the engineering and financing problems involved in sewerage planning for metropolitan fringe areas have been clearly presented by Mr. Klegerman. These problems are so varied in nature that there is no magic formula by which the sewerage problems of all fringe areas can be solved.

As pointed out by the author, the need is for comprehensive planning, and this can well be emphasized. In many cases two cities, or a city and its suburban area, find it advantageous to join a common project under a sanitary district or sewer authority. Examples include the Chicago Sanitary District,

the Minneapolis-St. Paul Sanitary District, the Hampton Roads Sanitation District, and others. In other cases—such as at Washington, D. C., as mentioned by Mr. Klegerman; at Nassau County, on Long Island; and at Buffalo, N. Y.—it has not been found practical for the metropolitan center and the fringe area to join in a common project.

In the cases where sanitary districts have been formed it may be noted that there are many factors common to all communities involved. There may be a common watershed, there is common interest and responsibility, common interceptors and plants are possible and economical, and over-all economy is accomplished. All these factors are present at Chicago, Minneapolis-St. Paul, and Hampton Roads. At Nassau County, on the other hand, the watershed is not the same as for Queens and Brooklyn, and the county facilities are large enough that there would be no economy in the use of the larger facilities of Queens and Brooklyn.

A unique situation is found at Nassau County, which makes the problem differ from that of the adjoining metropolitan center. The sandy soil in much of the county and the lack of waterways to receive wastes has resulted in extensive use of septic tanks. When rapidly increasing population made it necessary to replace septic tanks with sewers, a treatment plant was essential to provide a satisfactory effluent and a suitable point of discharge. Thus the plant was built before the sewers, and the county is currently in the midst of a program of building more than 1,000 mi. of collecting sewers to be tributary to the plant, which has been in operation for more than a year.

At Buffalo, an entirely different situation existed. Tonawanda and Amherst on the north, Cheektowaga and East Seneca on the east, and Lackawanna on the south, all had treatment plants years before Buffalo built its treatment works. When Buffalo finally undertook its program in 1936 to 1938, a common project for the metropolitan area was not practical, because it would have meant abandoning plants previously built and in operation and the construction of long and expensive interceptors to collect the sewage to one point.

The previous examples are of large cities and extensive fringe areas. In all cases, an analysis in the nature of comprehensive planning points to the correct answer.

The problem may be different for a city of moderate size.

The city of Elmira, N. Y., has just put into operation an enlarged and improved treatment plant. In the preliminary studies consideration was given to the possibility of forming a district to include Elmira and adjacent developed areas on three sides of the city. All areas are in the valley of the Chemung River, and could drain to a common point, with discharge of the effluent into the Chemung River. The question of having a joint project was particularly pertinent in the case of two suburban areas to the north of Elmira. In these areas there existed several relatively large industries. The areas also provided the locations for future industrial development. The sewage and wastes from these areas would discharge into a small stream, dry in the summer, flowing through a section of Elmira and into the Chemung River. A separate sewage treatment plant for these areas would be small, would have to provide complete treatment, and would receive a relatively high proportion of industrial waste. In fact a moderate-sized wet industry might contribute more load to the treatment works than the entire population of that suburban area.

When this situation was considered from the standpoint of encouraging possible industrial expansion, it appeared obvious that a combined project with one treatment plant to serve Elmira and its fringe area would be the best answer. Such a plant could

take moderate industrial loads, would require something less than complete treatment, and would result in over-all saving in operating cost. And this might be the best at even some additional first cost. The important factor here was to provide facilities favorable to further industrial development. This was a case in which the engineer should look beyond the strictly engineering questions and weigh the considerations in the light of the broader aspects of what is best for the community.

In another case, a village was requested by the developer of a housing project just outside the village, to take the sewage from the housing project. The treatment plant of the village is critically located and in some respects is overloaded. It is 15 years old. The answer from the standpoint of immediate problems would be to reject the request.

A few second thoughts may cast doubt on such a decision. The village is faced with plant enlargement in the near future to take additional load from increase of population within the village. There may be a question as to whether the plant should be enlarged at its present location. With prospective growth in the village and in the surrounding territory, the development of a sewer district appears to have possibilities. If some plan for new treatment facilities at another location and on a larger scale should be adopted, it might be reasonable for the village to take the flow from the housing project and struggle for a while with some overload at the plant. It would thus contribute to growth of its own community and the surrounding area. Obviously, some comprehensive planning is needed, and the answer to the immediate problem can then be made in the light of such planning.

These several examples of fringe area projects indicate that no two of them are alike, that each one must be studied individually, and that comprehensive planning based on all factors related to the welfare of the community is needed to arrive at the right conclusion.

One problem of serving fringe areas may be said to be of recent origin. It occurs when a major housing project is proposed adjacent to a developed area and is so located that it must have a sewer system tributary to that of the developed area. In the past this was not a major problem because growth was more gradual, health regulations were less strict, and the cost of sewage facilities was relatively lower.

When a modern large housing project, sometimes a city in itself, is to be built and needs sewers tributary to the system of an adjacent municipality, a problem of the "chicken and the egg" type may be presented. The sewer system cannot be extended first because there are no houses to serve, and thus property to be taxed or otherwise charged. On the other hand, health authorities may not permit houses to be built because there are no sewers and other facilities for sewage disposal are not acceptable.

The apparent answer to this problem is to have the developer build the sewers, but this may not be a complete answer. The design and the supervision of construction should be by, or at least under the control of, the municipality involved. There are also the questions of ultimate ownership of the system, who shall maintain it, and how the cost shall be finally met with fairness to the purchasers of the houses and others. It appears possible to include the cost of the sewers in the cost of the housing project, provide for deeding the sewers to the municipality in which the sewers are located, and have the house owners pay the charge for maintenance and operation of the system of which the project is a part.

RADON IN SEWAGE OUTFALL STUDIES *

By T. G. Bullen and William F. O'Connor †

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The apparatus described in the previous paper (1) was employed to make a preliminary survey of the radon content of natural waters in the area covered by the sewage systems under investigation (Figures 1 and 2). The findings of this survey were within the range of values given by Love (2), with the exception of the radon content of raw sewage. The concentrations that were found (Table I) were 10- to 50-fold greater than for similar waters in the neighborhood. This unexpected discovery led to attempts to trace sewage in the neighborhood of the outfalls by means of this natural radon as a tracer before considering the use of an added tracer.

Experimental Procedure

Samples of the various waters tested were taken in 1-gal. bottles at known times and shipped to the laboratory as rapidly as possible. Aspiration was usually carried out on the day of sampling, and the radon concentration determined in the manner previously described (1). The experimental values were corrected for the radon decay occurring during the time between sampling and estimation.

In order to determine that the activity measured was due to dissolved radon and was not being produced to any appreciable extent by radium in solution, the ionization chambers were held for several days and the activity determined at intervals. In all cases the activity decayed with a half-life of approximately 91 hr. in a strictly exponential manner, indicating beyond doubt that radon was responsible for the activity observed. Re-aspiration of water samples gave no measurable activity, even after several days, indicating the absence of appreciable concentration of dissolved radium.

Results

Table II gives the results for raw sewage and outfall waters for Mamaroneck. Table III gives the same data for New Rochelle. Table IV gives results for the South Yonkers treatment plant for raw sewage only. In this last case it proved too inconvenient to arrange for sampling at the outfall in the Hudson River during the period of the investigation. The samples at the outfalls were taken as near as possible to the center of the cone of dispersion. Tidal effects made the exact location of the correct position somewhat uncertain. It will be observed that the Mamaroneck raw sewage, on the aver-

TABLE I.—Radon Content of Natural Waters and Raw Sewage

Source	No. of Samples	Radon Content (10^{-12}c./ml.)
(*a*) Natural Waters		
New Rochelle water supply	5	2.0
New Rochelle H. S. lake	3	3.0
Iona College campus pond	5	2.8
Long Island Sound[1]	39	0.5–3.0
(*b*) Raw Sewage		
Mamaroneck treat. plant	8	89.9
New Rochelle treat. plant	14	60.1
South Yonkers treat. plant	12	42.2

[1] Except at outfalls.

* Presented before Division of Water, Sewage and Sanitation Chemistry, 122nd Meeting, American Chemical Society; Atlantic City, N. J.; Sept., 1952.

† Present addresses: Iona College, New Rochelle, N. Y., and Fordham University, New York, N. Y., respectively.

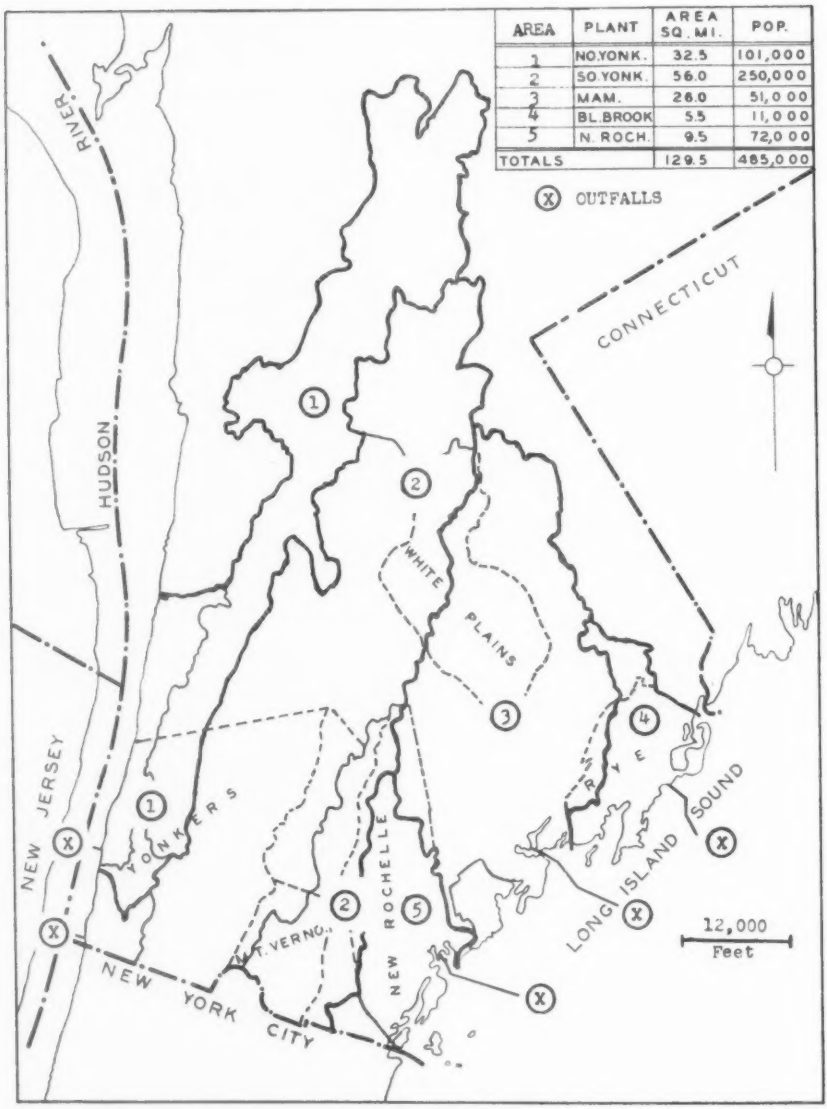

FIGURE 1.—Sewer districts of Westchester County, N. Y., 1952.

age, is decidedly richer in radon than either that of South Yonkers or New Rochelle, whereas the concentration at the outfalls of Mamaroneck and New Rochelle are almost the same.

The higher concentration of radon in raw sewage, compared with that of natural waters of the area, such as from ponds, lakes, and household service, is apparently due to infiltration into the sewers of waters relatively rich in radon.

From independent work carried out at Iona College for some 8 months

prior to this survey, it has been found that the gases in the soil contain much greater concentration of radon than was found in sewage. This radon is produced by the radioactive decay of radium compounds in the soil. During dry weather the radon escapes into the air after percolating up through the soil. In wet weather the rain traps the radon, dissolving some and impeding the escape of the rest. Table V shows the average concentration of radon in soil gases for the period from October 1950 to April 1951, as determined on the Iona College Campus at New Rochelle, N. Y.

Heavy rainfall causes the radon at depths below the percolation level of the water to increase, whereas the concentration close to the surface drops off considerably (Figure 3). These facts seem to indicate that quite a small infiltration could bring large amounts of dissolved radon into a sewer at times when infiltration occurs. In a similar manner, it would follow that radon, seeping into a sewer as a gas, could dissolve in the sewage to a noticeable extent.

Referring again to Table II, it is apparent that the ratio of the radon content of raw sewage to that found in outfall waters is the initial dilution of sewage entering open waters. The average ratio for Mamaroneck is about 30:1, that for New Rochelle about 20:1, with wide variations, presumably due

TABLE II.—Radon Content of Raw Sewage and Outfall Waters for Mamaroneck

Date of Sampling	Time of Sampling	Activity (10^{-12}c./ml.)
	(*a*) Outfall	
Aug. 16	Noon	1.86
Aug. 22	1:30 PM	0.53
Aug. 27	1:45 PM	6.20
Average		2.86
	(*b*) Raw Sewage	
Aug. 6	9:30 AM	83.4
Aug. 8	9:30 AM	106.2
Aug. 9	8:30 AM	70.7
Aug. 10	9:30 AM	84.7
Aug. 13	9:30 AM	98.4
Aug. 14	11:00 AM	117.1
Aug. 17	9:30 AM	91.5
Aug. 27	8:30 AM	67.0
Average		89.9

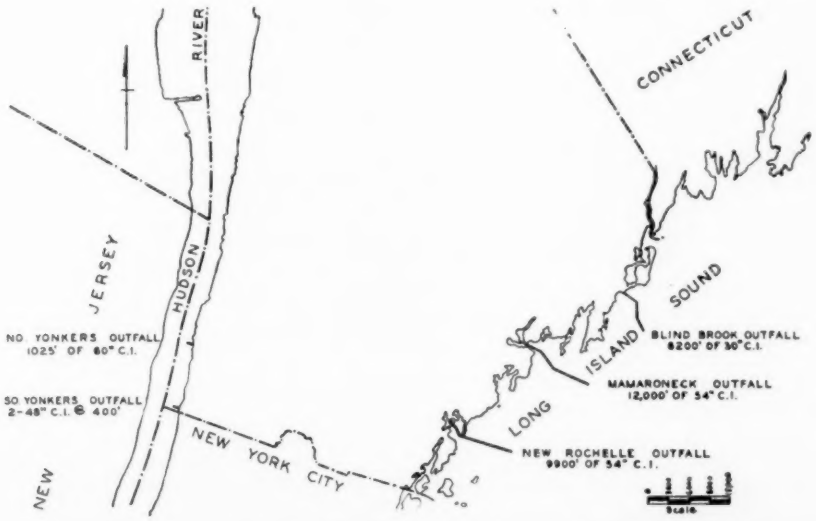

FIGURE 2.—Location and size of sewer outfalls, County of Westchester, N. Y.

TABLE III.—Radon Content of Raw Sewage and Outfall Waters for New Rochelle

Date of Sampling	Time of Sampling	Activity (10^{-12}c./ml.)
(*a*) Outfall		
July 24	10:00 AM	3.33
July 26	9:00 AM	5.70
July 26	9:00 AM	5.06
July 30	Noon	3.90
Aug. 1	2:00 PM	6.08
Aug. 2	2:00 PM	2.50
Aug. 6	2:00 PM	1.03
Aug. 7	2:00 PM	2.50
Aug. 8	2:00 PM	2.58
Aug. 13	2:00 PM	1.08
Average		3.38
(*b*) Raw Sewage		
July 10	9:30 AM	49.8
July 16	9:30 AM	57.0
July 18	8:30 AM	62.6
July 19	9:30 AM	54.1
July 19	9:30 AM	52.2
Aug. 2	9:00 AM	71.4
Aug. 2	9:00 AM	66.5
Aug. 3	8:30 AM	71.0
Aug. 6	9:00 AM	60.8
Aug. 8	8:30 AM	62.4
Aug. 10	10:00 AM	48.4
Aug. 13	9:30 AM	58.8
Aug. 17	9:30 AM	59.3
Aug. 20	8:30 AM	66.8
Average		60.1

to tidal and weather conditions. These values are in accordance with what would be expected in view of the mechanical and geographical arrangement of the respective systems. The Mamaroneck plant, the larger of the two, discharges into 50 ft. of water, at a point 9,000 ft. from the shore; that of New Rochelle discharges into 26 ft. of water only 4,500 ft. from the shore.

When sewage is discharged into a receiving body of water the initial dilution of raw sewage is of prime importance. Its determination is by no means easy, in spite of the several methods available. The various factors which control it are the rate of flow, the temperature and specific gravity

TABLE IV.—Radon Content of Raw Sewage for South Yonkers

Date of Sampling	Time of Sampling	Activity (10^{-12}c./ml.)
July 20	1:30 PM	43.3
July 25	9:30 AM	32.4
July 25	9:30 AM	37.2
July 26	10:30 AM	34.3
July 26	10:30 AM	38.6
July 26	10:30 AM	37.7
July 31	10:00 AM	57.6
Aug. 1	9:00 AM	48.8
Aug. 2	11:00 AM	57.1
Aug. 6	11:30 AM	39.8
Aug. 10	11:00 AM	32.4
Aug. 13	11:30 AM	46.8
Average		42.2

differences between the receiving water and the raw sewage, and the general tidal conditions. An estimation of initial dilution by purely mathematical means is unsatisfactory. The method presented here can give valuable information on initial dilution with relatively simple technique.

It was unfortunate that this aspect of the work was not developed more systematically. Limitations on the available apparatus used to carry out several types of investigation of an exploratory nature made such systematic approach impossible at the time.

The main purpose of the radon survey of Long Island Sound in the vicinity of the New Rochelle outfall (Figure 4) was to determine the natural radioactivity already present before

TABLE V.—Radon Content of Soil Gas[1]

Depth (ft.)	Radon Content[2] (10^{-12}c./ml.)
0	120
3	600
5	950
7	1,300
10	1,550

[1] Unpublished data: Iona College. A plot of these values against depth shows a definite tendency for the concentration to approach a limiting value at greater depth than used in these experiments.

[2] Values averaged over period from October 1950 through April 1951.

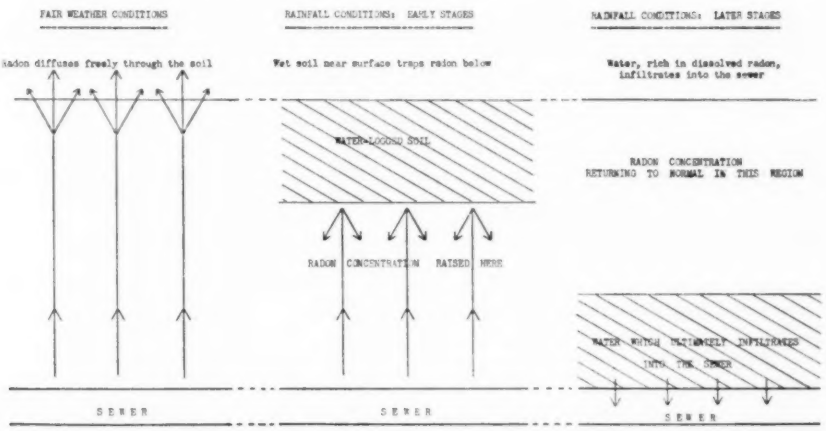
FAIR WEATHER CONDITIONS
RAINFALL CONDITIONS: EARLY STAGES
RAINFALL CONDITIONS: LATER STAGES
Radon diffuses freely through the soil
Wet soil near surface traps radon below
Water, rich in dissolved radon, infiltrates into the sewer
WATER-LOGGED SOIL
RADON CONCENTRATION RETURNING TO NORMAL IN THIS REGION
RADON CONCENTRATION RAISED HERE
WATER WHICH RECENTLY INFILTRATED INTO THE SEWER
SEWER
SEWER
SEWER

FIGURE 3.—How rainfall affects radon content of soil gas and sewer infiltration.

considering the introduction of a suitable tracer. Much of the time was spent in aspirating samples taken from a large number of points. The results of this survey (Table VI) are divided into two groups, one being northeast and the other southwest of the New Rochelle outfall. Table VII gives values for several beaches near the shore. In interpreting these results it must be borne in mind that the radon concentration from shallow waters may be increased by surface drainage and waters escaping from the ground beneath. The content is seen to be quite variable.

Owing to the peculiar tidal flows in the vicinity of New Rochelle, the direction of flow of tidal waters across the outfall is not predictable from tide tables alone. This is confirmed by unpublished results of dye tests carried out over the same period. However, some of the radon determinations conform with expected behavior. Referring again to Table VI: C 1H

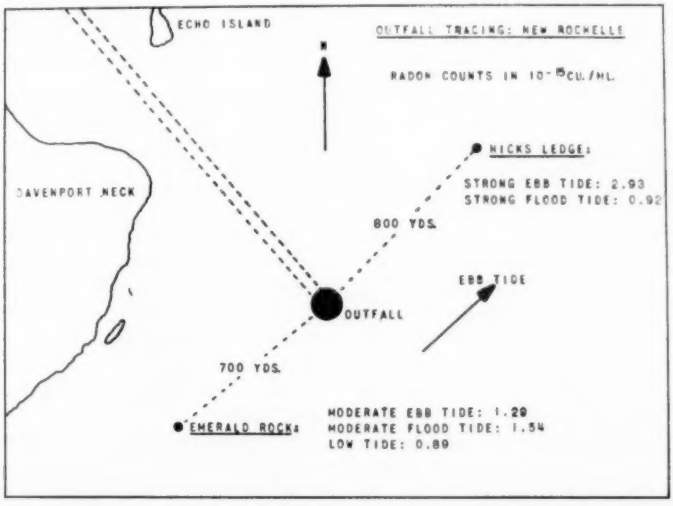

FIGURE 4.—Location of outfall tracing survey, New Rochelle outfall.

TABLE VI.—Radon Content of Waters of Long Island Sound Near New Rochelle Outfall[1]

Location[2]	Date	Radon Count (10^{-12}c./ml.)	Tide
	(*a*) Northeast of Outfall		
C 1H (Hicks Ledge)	Aug. 8	2.93	1½ hr. before low
	Aug. 22	0.92	2 hr. before high
C 3	Aug. 16	0.54	High
R 2	July 23	1.80	1½ hr. after low
	July 25	0.80	1½ hr. before low
	July 30	1.14	2½ hr. before low
	Aug. 1	1.13	High
Can 7	Aug. 2	0.25	1½ hr. after high
HBR	Aug. 2	0.28	1½ hr. after high
	Aug. 8	2.40	1½ hr. before low
R 40A	July 30	0.37	2½ hr. before low
R 40	Aug. 22	0.77	2 hr. before high
Toll Dock	Aug. 20	0.93	½ hr. before high
C5 – N6	Aug. 8	0.45	1½ hr. before low
3BR	Aug. 1	1.54	½ hr. before high
	Aug. 6	0.83	High
Plant dock	Aug. 21	1.83	½ hr. before high
	(*b*) Southwest of Outfall		
RB can (Emerald Rock)	July 24	1.54	½ hr. after low
	July 31	1.29	2 hr. after high
	Aug. 13	0.89	½ hr. before low
Fl. R14	Aug. 16	1.31	High
	Aug. 20	1.41	1½ hr. before high
CBS	Aug. 6	0.55	High
	Aug. 7	1.88	½ hr. before high
	Aug. 13	0.99	½ hr. before low
	Aug. 21	0.62	3 hr. after high
Texaco Dock	Aug. 16	0.85	2 hr. after high
	Aug. 20	1.19	2 hr. before high
Steven's Rock	July 24	1.21	½ hr. after low
NYAC	Aug. 16	1.32	3 hr. after high
	Aug. 20	1.04	1 hr. before high
Glen Island	Aug. 21	0.23	2 hr. before high
½ mi. E. of Huckleberry Island	July 31	1.68	2 hr. after high

[1] In open waters the incoming tide produces a southwesterly flow; for points near the shore the direction cannot be predicted with certainty.

[2] As listed in U.S.C. & G.S. Chart No. 222 corrected to May 14, 1951.

(Hick's Ledge), for instance—on August 8, with a northeast tidal flow, a high count was obtained, whereas on August 22, after a reversal of tidal flow, the count fell considerably. It is unfortunate that the counts for this point are so sparse, the aim of the survey being to cover a large number of points to determine the general activity of the area, rather than to follow its daily variation at a few selected points. A similar variation is seen to occur at 3BR and R2, in the latter the variation being cyclic over a tidal change. At the sampling point between CBS and Fort Slocum, in Table VIb, a low count was obtained except for August 7, which would indicate a southwesterly tidal flow for this date.

Although the number of counts made at any one particular sampling point is too small to draw conclusive evidence of tidal flow, the results indicate the

TABLE VII.—Radon Content of Various Beach Waters

Date	Location	Radon Content (10^{-10}c./ml.)
Aug. 14	1 hr. after high tide:	
	Glen Is. Beach	0.77
	N.R. Old Beach	0.66
	Pine Island	1.08
	Echo Bay Yacht Club	0.65
Aug. 28	2 hr. before low tide:	
	Nurses' Home	1.78
	La Rochelle	1.38

possibility of a tidal study in the vicinity of the outfall by daily determinations at three or four points over a complete tidal cycle.

Possible Improvements in Technique

It is obvious, in view of the radon concentrations encountered in the Long Island Sound survey, that the apparatus is insufficiently sensitive in its present form to carry out a thorough investigation of the ultimate fate of sewage by radon tracing. A much more sensitive electrometer system (Figure 5) has been employed by Hess (3) which would suit the present purpose admirably.

In the Hess method, two ionization chambers are used in a "balanced system," the radon in one chamber being determined by differences. This system has the advantage of eliminating, almost completely, the background of the apparatus, and allows the use of a more sensitive Lindemann electrometer. Two identical chambers are used, the outer walls being kept at + 250 v. and − 250 v. with respect to ground. The collecting electrodes are connected to the needle of a Lindemann electrometer, of sensitivity 50 to 100 divisions per volt, through a grounded shield. With the chambers filled with aged nitrogen, the needle is grounded and then isolated. Any differential change of the charges collected by the electrodes of the chambers produces a slow drift of the electrometer needle, due to difference in charging of the electrodes, the left-hand one collecting positive charge, the right-hand one collecting negative charge. If the left-

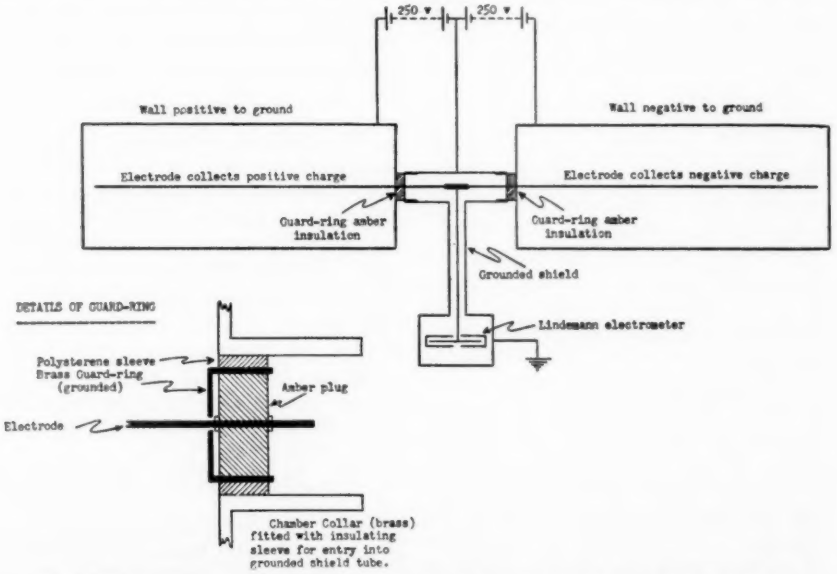

FIGURE 5.—Diagram of Hess double-chamber radon apparatus with details of guard-ring assembly.

hand chamber is then filled with the radon sample and the operation repeated, the effect of the radon can be determined by difference. Guard rings, around the amber insulation of the chambers (Figure 5), are used to cut down leakage current to a minimum. With such an apparatus it would appear possible to increase the sensitivity of the counting system by at least 50-fold. (Since the acceptance of this paper, a double-chamber radon apparatus has been constructed on the lines indicated in Figure 5. The guard-ring assembly was, however, somewhat modified to make construction easier. At an electrometer sensitivity of 100 divisions per volt (about 250 times the sensitivity of the Wulf apparatus used throughout this work) the needle drift due to background was found to be very small. Measurements of radon have been made to an accuracy of better than 5 per cent at concentrations that were just detectable with the Wulf apparatus. The ultimate accuracy obtainable is limited by the statistical variations of ionization current, always present in radioactive decay and more pronounced the lower the concentration of radon, rather than by the sensitivity of the electrometer.)

Consideration has been given to the possibility of using added radium as a tracer instead of depending on the naturally occurring radon. It would appear that a satisfactory test using about 20 mg. of radium could be carried out by injecting the radium into the outfall pipe at the treatment plant and carrying out a large number of samplings at increasing distances from the outfall. By holding these samples for 30 days, the resulting radon would be that in equilibrium with the radium present in the samples, the natural radon having decayed to an insignificant amount while standing. Assuming that the natural radium content of the samples is insignificant, the presence of sewage from the outfall would be positively indicated by the presence of radon on aspirating these samples. A few trials using fluorescein as a qualitative tracer could be used to indicate the best choice of sampling points and appropriate time schedule. This dye could also be used in conjunction with the radium solution to act as a visual method of control during actual tests.

Potentialities

The natural radon method of tracing appears to give a satisfactory procedure for estimating initial dilution at outfalls. Sewage systems that are rich in radon would offer the best opportunities.

A study of tidal effects on sewage disposal, along the lines previously indicated, could also be attempted in a systematic manner. Using radium as an added tracer appears to offer the best possibilities, especially if stagnation of sewage in shore pockets was to be investigated.

A study of infiltration into sewers appears feasible. By measuring the natural radon content at two points in a reasonable length of sewer which has no side connecting sewers, it would be possible to detect infiltration by a corresponding increase of radon content as the sewage flows downstream.

Acknowledgments

The authors acknowledge the encouragement of James C. Harding, Commissioner of Public Works, to undertake the program described, as well as the assistance he provided throughout. Thanks also are due to Henry Miranda, who ran most of the determinations.

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2. Love, S. K., "Natural Radioactivity of Water." *Ind. Eng. Chem.*, **43**, 1541 (1951).
3. Hess, V. F., "On the Radioactive Tracer Method in the Measurement of Water." *Trans. Amer. Geophys. Union*, Part II —Hydrology, p. 587 (1943).

BACTERIOLOGICAL STUDIES OF SLUDGE DIGESTION *

V. Optimum pH for Sludge Digestion with *Bacillus endorhythmos*

By C. E. Keefer, T. C. Buck, Jr.,† and Hester Hatch

Respectively, Deupty Sewerage Engineer, Bureau of Sewers; Assistant Director, Bureau of Laboratories, Baltimore City Health Department; and Senior Bacteriologist, Bureau of Sewers, Baltimore, Md.

One of the bacteria isolated from actively digesting sewage sludge, obtained from the Back River sewage treatment works at Baltimore, Md., was a Gram-positive, highly motile, facultative, anaerobic bacteria previously described by the authors (1) and called *Bacillus endorhythmos.*

As part of the study relating to the role played by this organism in digesting sewage sludge, it was considered essential to determine the pH value at which it was most effective.

Experimental Procedure

A quantity of fresh raw sludge was collected from one of the primary settling tanks at the Back River sewage treatment plant. This material contains approximately 9 per cent of activated sludge and 20 per cent of humus tank sludge, which are pumped into the raw sewage from the activated sludge units and the settling tanks following the trickling filters. The raw sludge was thoroughly mixed and then divided into seven portions. Six of the portions, each of which contained 3,000 ml., were placed in six 4-l. Woulff bottles. Each bottle was inoculated with 20 ml. of a concentrated suspension of *Bacillus endorhythmos.* The remaining portion was mixed with digested sludge (Table I) in such an amount that the ratio of raw dry volatile solids to digested dry volatile solids was approximately 2.6 to 1. The mixture of these two sludges, which served as a control and contained 3,000 ml., was stored in the seventh bottle. The sludges in the six bottles inoculated with *Bacillus endorhythmos* were maintained at pH values of 6.4, 6.8, 7.2, 7.6, 8.0, and 8.4. Since Baltimore sludge has been found to digest most rapidly at a pH of approximately 6.8, the sludge in the control bottle was maintained at this pH. Solutions containing calcium hydroxide and concentrated hydrochloric acid were used to adjust the pH values. The bottles were kept in an incubator at a temperature of 37° C. The gas produced by the sludges was collected in 5-gal. carboys, which contained a displacement solution (2) adapted especially where gases containing CO_2 are collected and measured. All gas measurements were corrected to a temperature of 0° C. and a pressure of 760 mm. of mercury. Samples of gas and sludge were collected and analyzed at regular intervals.

Results Obtained

The quantity of gas produced by the control and by the sludges inoculated with *B. endorhythmos* and maintained at the various pH values is shown in Figure 1. During the first 12 days the rates of gas produced by the control and by the sludges kept at pH

* Part IV of this series appeared in This Journal, **26**, 2, 164 (Feb., 1954).

† Now Research Bacteriologist, Bureau of Sewers.

TABLE I.—Analyses and Quantities of Undigested and Digested Sludge Used in Control

Item	Weight (g.)	Moisture (%)	pH	Dry Solids		
				Total (g.)	Volatile	
					(g.)	(%)[1]
Undigested sludge	1,875	93.85	5.6	115.31	77.26	67.0
Digested sludge	1,125	94.80	6.9	58.50	29.66	50.7
Ratio, undigested to digested	1.67	—	—	1.97	2.6	—

[1] Dry solids basis.

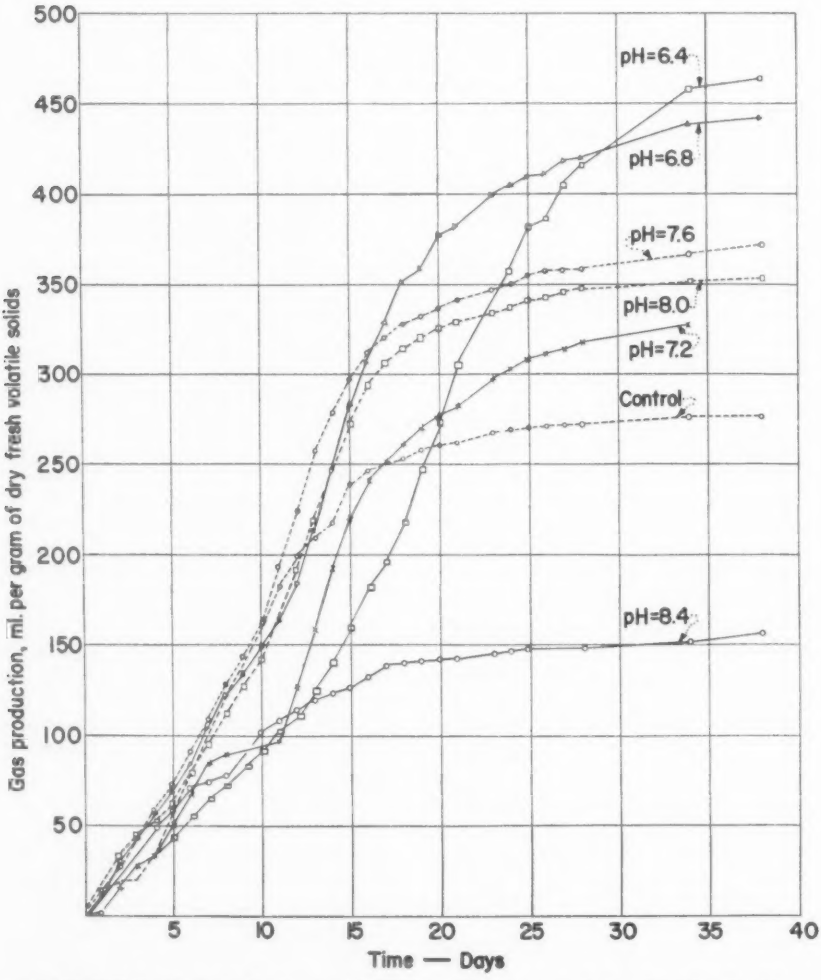

FIGURE 1.—Gas produced at various pH values by raw sludge inoculated with *Bacillus endorhythmos*

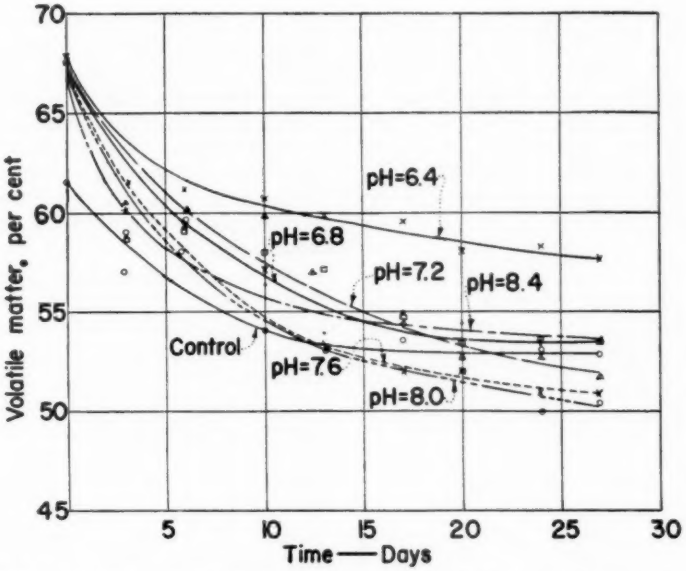

FIGURE 2.—Volatile matter in raw sludge inoculated with *B. endorhythmos* and kept at various pH values.

values of 6.8, 7.6, and 8.0 were the greatest, and the rates produced by the sludges kept at pH values of 6.4, 7.2, and 8.4 were somewhat less. At the end of 20 days the control had produced 261 ml. of gas per gram of dry fresh volatile solids and 278 ml. at the end of 38 days. The sludges maintained at pH values of 6.4, 6.8, 7.6, and 8.0 produced considerably more gas than the control. The maximum was produced by the sludge kept at a pH of 6.4, amounting to 464 ml. per gram of dry fresh volatile solids at the end of 38 days, or 67 per cent more than that produced by the control. Even the sludge kept at a pH value of 8.0 generated 27 per cent more gas than the control. Although the rate produced by the sludge kept at a pH of 6.4 during the first 12 days was less than that of the control and of the sludges kept at pH values of 6.8, 7.6, and 8.0, there was no appreciable decrease in the rate of gas production until after the 25th day, at which time 381 ml. had been produced. The sludge kept at a pH of 8.4 was the only one that produced less gas than the control.

Table II gives the moisture and the volatile matter in the sludges throughout the test period. The greatest reduction in volatile matter occurred in the sludge kept at a pH of 8.0, and the reduction in volatile matter in the sludges with pH values of 7.2 and 7.6 was only slightly less pronounced. The lowest reduction in volatile matter was in the sludge kept at a pH of 6.4. If the reduction in volatile matter is used as an index of sludge decomposition, the optimum pH was 8.0 (Figure 2). On the other hand, the greatest gas production was obtained when the sludge was kept at a pH of 6.4. These results indicate that the reduction in volatile solids at pH values from 7.2 to 8.0 was due largely to liquefaction and only partly to gasification.

Supplementary tests were conducted to see if *B. endorhythmos* was a lique-

TABLE II.—Analyses of Sludge During Digestion

Dig. Period	Control,[1] pH 6.8		Raw Sludge Inoculated with *Bacillus endorhythmos*																	
			pH 6.4			pH 6.8			pH 7.2			pH 7.6			pH 8.0			pH 8.4		
	Moisture (%)	Vol.	Moisture (%)	Vol.		Moisture (%)	Vol.		Moisture (%)	Vol.		Moisture (%)	Vol.		Moisture (%)	Vol.		Moisture (%)	Vol.	
(days)		(%)[3]		(%)[3]	Red. (%)		(%)[3]	Red. (%)		(%)[3]	Red. (%)		(%)[3]	Red. (%)		(%)[3]	Red. (%)		(%)[3]	Red. (%)
0	94.2	61.6	93.7	68.1	—	93.8	67.6	—	93.9	67.8	—	93.8	67.5	—	93.8	67.5	—	93.8	67.1	—
3	94.8	57.2	94.4	61.5	9.7	94.5	58.6	12.4	94.2	60.5	10.6	94.0	60.2	10.8	94.0	59.2	12.3	94.4	58.8	12.4
6	94.6	57.9	94.2	61.2	10.2	94.6	59.1	12.6	94.2	60.1	11.4	94.2	59.2	12.3	94.0	59.7	11.5	94.3	58.0	12.6
10	95.1	54.0	94.4	60.7	10.9	94.7	57.9	14.4	94.3	59.8	11.8	94.5	57.0	15.6	94.1	57.0	15.6	94.2	53.4	19.7
13	95.2	53.0	94.6	59.9	12.1	94.9	57.2	15.4	94.5	57.0	16.0	94.7	53.1	23.2	94.4	52.9	22.8	94.2	55.0	18.1
17	95.2	53.6	94.7	59.6	12.5	95.0	54.7	19.1	94.9	54.5	19.7	94.9	52.0	23.0	94.3	51.8	23.8	94.0	54.4	19.0
20	95.3	52.0	94.8	58.2	14.6	95.2	53.4	21.1	95.0	52.8	22.2	94.9	50.9	24.6	94.3	50.0	26.0	94.1	53.3	20.6
24	95.0	53.0	95.0	58.3	14.4	95.2	53.6	20.8	95.1	52.6	22.4	94.7	50.7	25.1	94.2	50.5	25.2	94.1	53.6	20.2
27	95.3	52.8	95.0	57.6	15.5	95.2	53.4	21.1	95.3	51.7	23.8	94.9	50.7							

[1] Mixture of 2.6 parts by weight of raw volatile solids to 1 part of digested volatile solids. [2] Dry solids basis.

fier or a gasifier. A quantity of raw sludge was sterilized in a specially designed container. Several attempts were made to sterilize the sludge in the conventional horizontal steam sterilizer without success. Satisfactory results were finally obtained by placing the sludge in an 18-in. length of 2-in. extra-heavy steel pipe, the ends of which were sealed. The sludge was then heated so that an internal pressure of 175 to 200 lb. per sq. in. was obtained in the container for approximately 30 min. Several samples of the sterilized sludge were inoculated with *B. endorhythmos*. In each instance there was no production of gas, but there was liquefaction and reduction of the volatile solids. These results indicate the organism is a liquefier, but not a gasifier. When raw sewage sludge is inoculated with the organism, it apparently lives in synergism with other organisms, which are directly responsible for the gasification of the organic matter.

Since unseeded raw sludge digests very slowly with little or no gas production and since it digested quite rapidly with the production of gas when it was inoculated with *B. endorhythmos*, this organism is evidently one of the organisms indirectly responsible for the gasification of the sludge solids. It apparently breaks down certain compounds which serve as a food supply for gasifying bacteria. Furthermore, it plays a vital role in sludge digestion, since its addition to the raw sludge stimulated gasification. If it were not added, gasification would have been greatly retarded. On the other hand, it was not necessary to add gasifying bacteria to the raw sludge at the same time *B. endorhythmos* was added to get gasification. This fact indicates that probably *B. endorhythmos* is present in small numbers in the raw sludge obtained in Baltimore and gas-forming bacteria are present in relatively large numbers.

Conclusions

The following conclusions, which are tentative pending the making of more extensive tests, apply particularly to the sludge collected in Baltimore:

1. *B. endorhythmos* was ineffective in gasifying sterilized raw sewage sludge. However, when unsterilized raw sludge was inoculated with this organism, rapid digestion occurred, with the production of gas and liquefaction of the organic solids.

2. The maximum gas production was obtained when the pH of the sludge was maintained at a value of 6.4. Somewhat smaller volumes of gas were produced when the pH was kept between 6.8 and 8.0. Except in the case of the sludge kept at a pH of 8.4, the volume of gas produced per gram of dry fresh volatile solids was greater than that produced by the control.

3. The reduction of volatile solids in the sludge inoculated with *B. endorhythmos* was greatest at pH values of 7.6 and 8.0 and least at a pH of 6.4.

4. *B. endorhythmos* was most effective in decomposing sludge over a wide range in pH values.

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BACKLOG OF SEWAGE WORKS CONSTRUCTION NEEDS

In a recently released report, the U. S. Public Health Service has outlined the backlog of sewage works construction as follows:

1. Sewage and industrial waste treatment is currently proceeding at a $600,000,000 annual construction rate, but a $1,800,000,000 rate is necessary to eliminate the backlog in five years and also provide for the current population growth (1).

2. During the period 1947–52 sewage works construction, in terms of 1952 dollars, totaled $2,726,000,000 (2).

3. The estimated sewage works construction backlogs at the end of 1952 and 1960 are as given in Table I.

References

1. "Economic Report of the President." Page 105 (Jan., 1954).
2. "Construction and Building Materials." Statistical Supplement, U. S. Dept. Commerce, pp. 11, 16, and 32 (May, 1953).

TABLE I.—Sewage Works Construction Backlog Estimates[1] as of Dec. 31, 1952, and Dec. 31, 1960

Date	Needed Construction[2]				
	Public Sewage Works			Indus. Waste Treatment	Total Public and Indus.
	Collecting Sewers	Interceptors and Treatment	Total		
Dec. 31, 1952[3]	1,669	2,500	4,169	2,500	6,669
Annual, 1953–60	140	200	340	200	540
Dec. 31, 1960	2,789	4,100	6,889	4,100	10,989

[1] Estimates based on Division of Water Pollution Control data.
[2] Millions of 1952 dollars.
[3] Based on up-to-date adjustment of "Nation-Wide Inventory of Sanitation Needs." Supp. 204 to *Pub. Health Rep.* (Apr., 1948).

Industrial Wastes

1953 INDUSTRIAL WASTES FORUM *

DON E. BLOODGOOD, *Leader*

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Chairman Bloodgood:—For a number of years there have been discussions of specific waste controls whenever two or more people interested in industrial wastes have met. Usually, the individuals have considered themselves to be in disagreement, particularly when the discussion was on a specific topic. This difference in opinion has led many to believe that there is wide divergence of opinion even on the most fundamental aspects of the industrial wastes problem. Someone once said, "You cannot talk pollution out of a stream; neither can you fine pollution out of a stream." But agreement on the general principles of pollution control is a step in the right direction, and it is in the interests of such agreement that this forum is being held.

The staff and advisory committees of the Ohio River Valley Water Sanitation Commission have expressed their concepts of these principles in the following brief form:

1. Regulations for the control of industrial waste discharges shall be designed to safeguard and maintain water uses that will serve the public interest in the most beneficial and economic manner.
2. The determination of water uses shall be made on the basis of need.
3. Suitability of water for specific uses shall be defined in terms of quality criteria.
4. The stream shall be used to some extent for waste treatment.

There may be some who do not agree with these very general statements, but the opposition surely is limited.

As soon as discussion turns to the specific means of carrying out the general policies, however, arguments are apt to start. Such a discussion can result in the locking of horns and the bitterest of remarks. The inclination to do this can be curbed to some extent, however, if the discusser will keep in mind that when he objects to the solution presented by someone else he should be prepared to give a constructive statement on how to accomplish the desired mission by his plan.

The panel members selected to lead this forum are men of courage, because at least a like number have declined to participate as discussion leaders. Perhaps this indicates that some "hot" topics have been selected.

Criteria for Stream Usage

The first of these topics concerns the criteria to be used in assessing the value of a stream as a useable method of waste treatment or disposal. Obviously, this question is as controversial as any and should arouse considerable discussion.

Harold Jacobs, E. I. du Pont de Nemours and Co., Wilmington, Del.:—Before the discussion begins it should be understood that my remarks here pertain to my own views and do not represent the official views of the Du Pont Company.

* From transcript, 26th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Miami, Fla.; Oct. 13–16, 1953.

It would appear that the quality of water at the point of use should be the governing factor in pollution abatement. This, of course, precludes the use of either stream standards or effluent standards. The use of water quality criteria as a measure of pollution abatement needs is by far the most difficult control measure to apply, but it seems the only fair way of enforcing treatment requirements. No other procedure gives full use to the assimilative capacity of the receiving waters. Consequently, no other procedure will result in minimum expenditures for sanitary and industrial waste treatment. The capacity of our streams for absorbing wastes without damaging the water for subsequent uses is enormous.

Flowing streams are in themselves giant treatment systems. When present in reasonable amounts, the breakdown of organic matter begins immediately with the development of the proper bacteria to utilize the biochemical oxidation process as their energy source. The replenishment of the lost oxygen by re-aeration begins at the same time. Some of the alkalinity in the water can be absorbed or utilized by waste acids with little effect on the pH or conductivity. The dilution of soluble salts for purposes of disposal is a perfectly legitimate use of a stream. Naturally, discretion and common sense must be used in deciding when and how much untreated waste may be absorbed. In principle, there is nothing wrong with such a stream utilization. The question is one of degree only, since the finest of treatment plants will still discharge some unaltered waste for the stream to assimilate.

For purposes of discussion, I would like to pose one question. In a case where a single water user is damaged by upstream pollution is it ethical for the polluters to pay the added treatment cost suffered by the user rather than the treatment costs of the wastes at the point of addition? I have an actual case in mind, where a small municipality has an unsatisfactory water supply because of phenols discharged by several industries upstream. The cost of treatment prior to discharge would involve large expenditures. The water use below the municipality is unaffected because natural purification is adequate at present to protect other users. Is it ethical and legal for the industries to subsidize the municipality for the additional equipment and operating cost for chlorine dioxide treatment of the water it uses, rather than to spend the much larger sums individually required for their own waste treatment works? I firmly believe that it is. That is a good example of the correction of a pollution problem by evaluating all factors of it and by selecting the least expensive over-all measures. The water quality criteria would, in this case, dictate the enforcement action.

My talking against stream or effluent standards is no accident, because I am against the use of either. It is not my purpose, however, to discuss their relative merits or demerits, because other speakers are scheduled who will do that more ably.

Clair N. Sawyer, Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.: —As regards this matter of polluting the stream and then taking it out again in the water treatment plant, the difficulty, of course, is that most plants discharge into the stream below their water supply intakes. If the suggested system is going to work, plant A, which is just upstream, should be responsible for the water purification of plant B, which is below, and plant B would be responsible for water purification of plant C, etc. How would that be managed?

Mr. Jacobs:—It couldn't be managed, of course, if an attempt were made to apply that principle on a general scale all over. I am thinking, of course, of a specific situation or two.

One that I have heard quite a bit about involves phenol, but the problem could be better met at the municipal water treatment plant, which does not have the equipment. The water system of course, would have to raise money by a bond issue and taxes on property, industry included, in order to put in super-chlorination, activated carbon, or some treatment of that type. In the particular case in mind, a great deal of resistance is being expressed to the idea that the industry should be allowed to finance that sort of thing. An attempt is being made to hold the industries to a rigid effluent standard of 0.05 p.p.m. of phenol, a requirement it will be very expensive for them to meet.

If 20 water companies were taking water out of that stream within a matter of a very few miles, it probably would not be practical to attack it in this way. But phenol does gradually go to pieces under the action of bacteria and, in this case, the next water plant down the line probably would not be bothered. In other words, control agencies should be flexible in their thinking and should not apply the same general reasoning in every case. There are extenuating circumstances, in many cases, which should be given consideration. If the control agency is open-minded and is willing to talk across the table with all of those involved, in many cases a much more reasonable solution can be arrived at than by simply saying: "This is what you've got to meet, go ahead and meet it."

George E. Symons, Consultant and Technical Editor, Larchmont, N. Y.:—What legal rigmarole is involved in getting the industry to pay for the cost defrayed by the municipality? Phenol has been mentioned as a specific problem. What kind of legal arrangement is to be set up for a municipality to assign that charge to the industry?

Mr. Jacobs:—Not being a lawyer, I can't tell in terms of law how that should be done. All parties concerned should know exactly what is being done, however, so that the whole thing is open and aboveboard. It is easy, of course, to decide how much and what kind of equipment is needed to improve the water supply, and arrive at a cost in dollars. Providing the control agency agrees that that is an equitable solution to the problem, the industries themselves can then get together on whatever basis they wish—perhaps the amount of phenol which each discharges—and split the cost in that way. It has been done in that way on sewer lines, for instance, where commercial buildings, industries, the municipality, and even the county, have all paid part of the cost of installing an interceptor. There was no difficulty in getting together, once the county accepted the principle of payment on the basis of contributed flow.

Kenneth S. Watson, Coordinator of Waste Treatment, General Electric Realty Corp., Schenectady, N. Y.:—The suggestion to treat water, rather than to treat industrial wastes, brings out the fundamental principle that the most economical method must ultimately prevail. If all the ramifications are considered, it may be that a phenol discharge that is merely messing up the water supply for one municipality, and has no objectionable effect on the other uses of the stream, could be more economically handled by that community or the industry by providing for the treatment of the water. Of course, the necessary changes would have to be made in the law to permit the municipality to charge the industry for the service.

Hayse H. Black, Chief, Industrial Wastes Section, USPHS Environmental Health Center, Cincinnati, Ohio:—This is a bold offer on the part of Mr. Jacobs. Some real problems enter into the picture in trying to operate a water plant receiving a considerable amount of varied industrial waste. Phenol has been suggested as one. However, anyone who has spent any time in a water

plant will recall that it is a real problem to get complete coverage. It may be planned to operate with chlorine dioxide on a level high enough never to be reached with phenol concentrations, but that is easier said than done. The chances are very good that sooner or later some objectionable water will get through into the distribution system, and then the complaints will begin.

This is the first time that I can recall where an industrial representative has offered such a program, despite the fact that he has specifically disclaimed the idea as binding on his company. The suggestion, of course, is not new, having been put forward about 15 years ago. The fact that it hasn't been adopted too widely, however, should introduce a note of caution.

Milton P. Adams, Secretary, Michigan Stream Pollution Commission, Lansing, Mich.:—Mr. Jacobs seems to have thoroughly covered the significant points in his outline of the general criteria involved. His proposal, however, would hardly apply to problems that have arisen in Michigan. A good example is the situation necessitating the new pipeline serving Saginaw and Midland, for instance. In 1935 water supplies were taken both at Saginaw and at Bay City, and involved a combination, not only of phenolic wastes, but also of brine from the Dow Company, as well as from the oil fields. There were some phenols from refinery operations, and sugar beet wastes in season. The matter of water supply was the only thing it was felt could not be taken care of properly by adequate treatment, simply because the public was so concerned.

The operator may take care of that problem 29 days out of the month, but if he lets go on the 30th day, the phone rings and makes just as much trouble for the local public administrator as though the plant had been out of service more than that time.

With numerous water supplies on both sides of the U.S.-Canadian boundary waters, such a proposal as has been offered would not be satisfactory. Detroit's costs alone, if the phenol problem is not controlled, are alleged to be at least $200,000,000. A part of the Detroit metropolitan area is even thinking of going to Lake Huron for its water supply, simply to get away from the phenol problem in local waters.

An excellent job has been done in recent years at Midland by the Dow Chemical Co. The reports show that by treatment they are reducing the applied phenol from wastes amounting to some 3,900 lb. per day to less than 100 lb. per day; in fact, 50 to 75 lb. per day is the average that goes into the river. Among the major benefits is elimination of the tainting of the flesh of fish, an important industry in the Saginaw Bay area. Despite relieving of the phenol load, public opinion demanded as well that Saginaw and Midland seek a new substitute source of water.

Water Dilution Factors for Industrial Wastes

Chairman Bloodgood:—Another extremely controversial matter is that of dilution factors that should or may be used for stream disposal of industrial wastes. That all is not "rosy" is borne out by the next speaker.

Richard D. Hoak, Senior Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa.:—Dilution of stream water is generally believed to be invariably beneficial. Since the most common sort of stream degradation occurs as a result of depletion of dissolved oxygen, it would seem only logical that dilution should serve as a corrective. Unfortunately, the problem is not that simple.

Before the classic experiments of Streeter and Phelps led to an understanding of the mechanism of oxygen depletion and reaeration, various ratios of stream flow to population were used to control pollution. Stream flows of

2.5 to 3.5 c.f.s. per 1,000 population were considered minima for inoffensive assimilation of domestic sewage. Where esthetic considerations were paramount, flows ranging up to 10 c.f.s. per 1,000 were required. These flow-population ratios are applicable where oxygen balance is a prime factor; where the permissible concentration of *E. coli* has to be considered, dilution must be some 500-fold greater.

Statistical analyses of data collected by modern assay techniques permit accurate evaluation of the assimilative capacity of streams. These procedures take proper cognizance of dilution and the role it plays in stream self-purification. Application of modern methods in stream survey work has disclosed that dilution is not always the favorable agency it was formerly thought to be. In any program of stream evaluation, dilution is only one of a number of factors that must be related to each other if a sound conclusion about assimilative capacity is to be reached. Where industrial wastes are involved the problem is usually much more complex than for domestic sewage alone.

The literature on improvement of water quality by dilution is rather meager. It is usually assumed that dilution is beneficial, and the recommendation naturally follows that it be provided wherever possible. The report of the Ohio River Committee states that construction of dams solely for low-flow augmentation would not generally be economically sound. It is pointed out, however, that where the cost of such reservoirs would be less than the difference between the cost of primary and secondary treatment for one or more communities, their construction might be justified.

Where low-flow augmentation is practiced, it is usually one planned function of a multipurpose reservoir. Where flood control is the primary function of a reservoir, it is clear that such basins should be practically empty during the normal flood season or they will fail in their purpose. In some parts of the country floods usually occur during the winter and spring months. In such regions it would be practical to release water from a full reservoir during the summer at a rate that would use up the impoundment by late fall, but flooding rains do not everywhere conform to such convenient uniformity.

Aside from flood control dams, low-flow augmentation is often supplied by hydroelectric installations. In these cases, runoff is stored during months of heavy rainfall and released through the turbines in accordance with the demand for energy. This means that low-flow augmentation is incidental to efficient power plant operation, rather than to stream needs. It is not unusual to find the demand for power much lower from late night to early morning, which results in a lower discharge of water during such periods. Thus the average flow of a stream below a hydroelectric dam could be relatively constant while the actual hydrograph would show wide fluctuations. Where such conditions prevailed on a fairly heavily polluted stream which depends in part on aquatic vegetation for reaeration, the hydro dam might actually be deleterious to stream water quality, because of the diurnal effect.

The study of Camp, Dresser, and McKee on the Clarion River (Pa.) disclosed another type of situation in which dilution would be deleterious. There is a dam on the Clarion below a number of sources of pollution, the chief of which is a large paper pulp mill. This reservoir has acted as a huge settling basin for organic solids since its construction in 1924. The solids undergo slow bacterial decomposition, and this results in a serious drain on the D.O. of the water passing through the reservoir during dry seasons. A flood control dam is under construction on a tributary of the Clarion above the largest sources of pollution. Regulated release of water

will roughly treble the low flow of the river. An analysis of expected D.O. profiles has shown that construction of another reservoir, upstream from the 1924 basin, would actually worsen stream water quality because the increased low-flow would serve merely to keep solid matter in suspension until it reached the proposed reservoir. This could be overcome only by providing waste treatment adequate to hold the D.O. above 4 p.p.m. at all upstream points.

The upper Ohio River illustrates another condition in which low-flow augmentation would be deleterious. The river receives raw sewage from a population of about 1,000,000 persons, but it also carries such a heavy load of acid mine water that normal bacterial activity is inhibited. If the river water were diluted with enough low-alkalinity water to overcome the effect of mine acid, the river below Pittsburgh would become a great cesspool.

Where flood control reservoirs are used for low-flow augmentation, it has been reported that taste and odor problems have increased.

What has been said so far implies that dilution is deleterious rather than beneficial. This is not the case, of course. Difficulties have been cited only to emphasize the fact that low-flow augmentation is not necessarily a universal panacea for stream pollution problems. Velz has pointed out that nothing can be done to regulate the discharge of domestic sewage, but that operation of industrial plants can often be adjusted to anticipated stream flow. Where advantage can be taken of daily trends in natural purification capacity, plants that are now restricted by water resource limitations would be benefited, and over-all water quality improved. This might well be a better approach to unsatisfactory stream conditions than seeking high-cost dilution water.

Nothing has been said about toxicity, because insufficient data are available to define the degree of dilution that would yield a toxic threshold. When the bibliographic surveys being undertaken by industry committees, under Orsanco sponsorship, have been completed it may be possible to discuss this subject with real knowledge.

Mr. Watson:—On an area-wide basis dilution probably has very broad applications for industrial wastes control. Nevertheless, industrial representatives should not deceive themselves about dilution.

Dilution sometimes can be quite costly. The water needed to dilute a waste to a point to where it is satisfactory may appear cheap, but when you start paying the water bill you get a different viewpoint. Where it applies to an individual plant, dilution probably is not an answer to the wastes problem, particularly if clean water must be taken from the city or from the industry's own water treatment plant. On the other hand, if it is possible to use for dilution clean water which must be disposed of anyway, that's one thing; that would be a sound approach. But to use clean water merely for dilution is not a sound approach.

Frank W. Jones, Havens and Emerson, Consulting Engineers, Cleveland, Ohio:—I am a great believer in dilution, provided it dilutes. I have in mind one stream in a park area. Now, certain things can be tolerated in some streams, but a park stream where children play should be of the best quality.

Raw sewage was discharged to this stream in an upstream location, making the stream filthy in that reach. Yet, even under low-flow conditions, 2 mi. downstream the water was clear, there was a little algae on the bottom, the bacterial count was low, and it had all the evidences of being a good stream. If a sudden downpour came, however, not giving sufficient time for purification and dilution, that festering mass from upstream was carried down into the clear section. It was perfectly right

and proper, therefore, that the sewage should be taken out of that stream.

Dilution *per se* doesn't always accomplish what it is intended to. However, if there is enough water to take away the visual evidences of sewage and to give the fish enough oxygen to live on without coddling them too much, the benefits of dilution are factual and real.

Voice from the Floor:—Definite stream standards or effluent standards may be troublesome, but human nature being what it is, sometimes we have to make use of them as a starting point. Florida streams are learning to use a great deal less than 3.5 p.p.m. of dissolved oxygen. The Florida State Board of Health generally has been very understanding in the use of the state's streams. They have recognized that the streams are useful in handling waste, and can do a job which would be economically difficult to do in a treatment plant.

Do I understand Mr. Hoak correctly when I interpret his remarks to mean that flood conditions in the Ohio River valley will give dilution, but the river will still become very foul?

Mr. Hoak:—The interesting and unfortunate thing about the flow of water from mines is that the concentration of dissolved salts remains relatively constant; that is, the heavier the rainfall, the more drainage from the mines and the greater the total weight of dissolved salts that reach the river. It is true that during a period of heavy rainfall there will be considerable dilution by water that does not contain mine acids. The effective rainfall is not as effective, however, in providing pure water in the Ohio as one might think, because of this unfortunate fact that the concentration remains relatively constant regardless of the flow from the mines.

Chairman Bloodgood:—This question was raised because some people have made the statement that all pollution problems could be settled by the construction of dams and the release of water. Others, who have believed this for a number of years, have now come to the conclusion, after experience with flows controlled only by power companies, that the result was worse than without the controlled flow as provided by the power dam.

Classification of Stream Sections *vs.* Entire Stream

The third of our "hot potato" questions concerns pollution abatement on the basis of natural purification capacity of sections of streams *versus* entire streams.

F. W. Kittrell, Process and Sales Engineer, Frederic B. Stevens, Inc., Detroit, Mich.:—Stream pollution control laws of a number of states require that the streams be classified before the enforcement authority of the control agencies can be brought to bear on municipalities or industries causing stream pollution. In several other states, where stream classification is not required by the basic legislation, the control agencies have adopted the classification system as a basis for decisions regarding degrees of reduction needed at sources of pollution.

The individual or agency responsible for establishing a classification system has a wide range of possibilities from which to choose in determining the degree of refinement with which the system shall be applied. A few states have solved this quite simply by saying, in effect if not in fact, "All of our streams shall be Class A." Those states that have adopted high minimum water quality standards for general application to all streams have, in effect, designated all of their streams as Class A.

At the other extreme would be an attempt to break each stream down into minute sections and classify it yard by yard, rod by rod, or even mile by mile. Such an attempt would be doomed from the start. The science of stream sanitation is not sufficiently ex-

act and streams are too complex and variable to permit such precision.

It is rare that the most practical solution of any problem is found at either extreme of the range of possible methods of solution. This discussion deals with classification of an entire stream *versus* classification of stream sections. An attempt will be made to bring the discussion from the realm of abstraction, with its easy generalities, down to mundane reality where facts must be faced and decisions made. This can be done best by visualizing a stream flowing through several types of areas and being used for several purposes.

This stream rises in a mountainous region, through which it tumbles for many miles before it reaches the more gentle slopes of a highland area, and finally flows through a large bay in the coastal plain to enter the ocean. The tumbling, sparkling section in the mountainous region abounds with trout, and its beauty attracts many tourists for purely aesthetic enjoyment. An industrial plant located near the upper edge of the highland area uses the stream as a source of water supply and discharges its wastes into it. A dam near the lower edge of the highland area impounds most of this section of the stream. Although its major purpose is the production of power, the reservoir has, as a by-product, recreational value for fishing, swimming, boating, and vacation cottages. A large city, located near the upper end of the bay, uses the lowland section of the stream as its source of public water supply. The bay receives the sewage from the city, and also provides a harbor which brings the city important income.

Should a single classification be applied to a stream with such diversity of sectional characteristics, uses, and needed water qualities?

The income from trout fishermen and tourists visiting the mountainous region justifies maintenance of the highest water quality to protect the sensitive trout and the aesthetic qualities of this stream section, which is designated as Class AA. This quality is entirely adequate for the source of industrial water.

An investigation of the industrial plant's wastes and the stream below reveals that a reasonable degree of treatment will maintain Class A water in the reservoir, but treatment sufficient to achieve Class AA water would cost so much that a reasonable margin of profit for the plant would be endangered. Class A quality is adequate for all recreational uses of the reservoir water. This quality will permit the hardier bass, crappie, and perch to thrive, and is far better than required for power production.

The lowland section of the stream, below the reservoir, also is Class A, and preferably should be maintained in this class, since it serves as the source of public water supply for the city. The city's modern filtration plant could produce potable water from Class B stream water if necessary, but only an exceptionally compelling reason should be accepted as the basis for a decision to permit degradation of this section from Class A to Class B.

The bay below the city need not be of high quality to carry away the city's sewage and to serve the needs of navigation. Fishing is not important in this section. Odor and visual nuisances should be prevented, and the water should not be corrosive to metal structures. Class C quality can be maintained by primary sewage treatment, but secondary treatment would be required to achieve Class B or better.

If a single classification were to be adopted for the entire stream the desires and expenditures of the trout fishermen and tourists might prevail, with the assignment of Class AA from the mountains to the sea. This would be the simplest procedure, technically, that the pollution control agency could follow. It would not require detailed

investigation of all stream sections and individual evaluation and decision regarding the needs and potentialities of each. The maximum possible treatment of all wastes would be required. On the other hand, it could prove to be the most difficult procedure from the administrative and enforcement standpoint. It would involve needless and excessive costs to the industry and the city, and could lead to resistance and persistent delay in compliance with the control agency's requirements. Establishment of this high classification also would threaten the industrial future of the region by making it almost impossible for potential new industrial plants to meet the cost of the high degree of waste treatment necessary.

At the other extreme it would be unthinkable to place the entire stream in the lowest classification, Class C, which is adequate for the section below the city. This would destroy the valuable recreational resources of the upper stream section and the reservoir, and could seriously cripple the city's water supply. It would discourage the location in the area of new industries that require good quality process water.

It would be more nearly reasonable, perhaps, to classify the entire stream in one of the intermediate classes, A or B. Either of these, at best, would represent a questionable compromise that could be avoided by the application of sound sanitary engineering principles and judgment to the task of classifying the stream by logical sections based on uses and needs in the several areas. When the handbook approach to stream pollution control is adopted by blanketing entire streams and all streams under a single set of rigid standards, the justification for engineers in stream sanitation programs is minimized. When, on the other hand, professional training and experience are called upon, and ingenuity and judgment are exercised in establishing the most equitable and economical requirements possible for each situation, we fulfill our missions as professional engineers. This approach assures the best and most logical use of one of the country's most essential natural resources. It yields individuals concerned a bonus in the form of personal satisfaction derived from a job done to the best of their abilities.

Voice from the Floor:—To maintain certain specified sanitary conditions in the stream, should one user be penalized so as to permit another user an unrestricted and uncontrollable use of the stream? Or, to put it more specifically, in the hypothetical case just presented should the city have to treat its sewage to a high degree so that the vessels coming into the harbor might still spew untreated sewage and bilge water into the bay?

Mr. Kittrell:—All of us talk about the capacity for waste disposal being one of the resources of our streams. I am a firm believer in this, but I'm afraid most put that at the bottom of the proper uses of a stream. For this reason, most people seem to feel that waste disposal should not interfere in any way with any other use of water—that all other uses of water should have priority over waste disposal.

Waste disposal rightly should take its proper place, even though it may interfere with some of the other uses; even though it may cost a little more for water treatment, which it undoubtedly does; even though it might limit certain sections of the stream for swimming, so long as other sections nearby are available.

These factors should be taken into consideration and more importance placed on the fact that it is proper and right for waste to be discharged through a stream.

Chairman Bloodgood:—Although swimming is important, it is not necessarily the most important use for a stream. There are many instances in which waste disposal is of more importance to a community or a region

as a stream use than is swimming. Balancing of all the factors certainly would show many cases where there is a just place for the use of streams in waste treatment.

Professor Sawyer:—What about the case where two tributaries join to form a third stream? What standard is going to govern? Who is going to have the final say as to what condition the standards are to be designed for?

Mr. Kittrell:—Supposedly it would depend on the use of the water in the stream flowing from the two tributaries. If there is a water supply just below the junction, both tributaries should be so handled as to protect that water supply. Or if there is any other use, the tributaries should be handled so as to protect that particular use. It doesn't make a great deal of difference whether the pollution comes down from upstream on a single stream, or whether it comes down from one tributary or several. Each section must be handled in the light of the water use in that section and in the sections downstream.

W. H. Larkin, Chief, Water Pollution Control Section, State Department of Health, Albany, N. Y.:—What Mr. Kittrell has said is largely an endorsement of the law and the thinking of the stream pollution control agency in New York State. His description regarding the zoning or dividing of a stream into different sections for classification by determining its best usage, represents an extremely simple case.

In actually working with these things, much more complex problems are involved. For example, any one section of a stream may have multiple uses, which must be so balanced as to determine the single use, for that stream, which best serves the needs of the community involved. Under the New York State regulations, any source of pollution or discharge into a section of a stream which causes deterioration of the quality of the water in a section of stream of higher class below, is in violation of the law. In other words, despite the fact that a discharge may not violate the standard at the point of discharge, if its effect carries down through the stream and results in a violation of the standards in a lower section of the stream, the discharge would still be in violation of the law.

Mr. Kittrell:—Under the existing law in New York State, how often could streams be re-zoned? What legal procedure is involved?

Mr. Larkin:—The law provides for re-classification of a stream section after a public hearing; the same as a public hearing is required before an initial classification. It could, if required, be done in a relatively short time. The only legal restrictions on time would be those required for the hearing notice (20 to 30 days) and the time required for the legal action of the Board after the hearing.

Chairman Bloodgood:—What is considered the most important use for a stream?

Mr. Larkin:—The most important use might not necessarily be the one requiring the highest quality. In other words, even if there were, for example, swimming and fishing in a highly industrialized area, the most important use for that stream, or that section of the stream, could be as an industrial water supply. That would mean, of course, that the Board is not obligated to maintain that stream at a high enough quality for bathing, or for the survival of fish. In other words, it's a matter of judgment by the Board, but only after a public hearing in the affected community.

Stream *vs.* Effluent Standards

Chairman Bloodgood:—The only way I know of settling so controversial a problem as the one of stream standards *versus* effluent standards is to do as is being done here—open it to forum discussion and get the opinions of leaders in the field from various parts of the country. It takes Texan cour-

age, however, as well as an exceptional grasp of the subject, to undertake the task of leading such a discussion. The next prepared speaker obviously has both these qualities.

F. R. Herzik, Jr., Chief Engineer, Bureau of Sanitary Engineering, Texas Department of Health, Austin, Tex.:—To schedule "Stream Standards *versus* Effluent Standards" as a subject for discussion seems to represent a lightly camouflaged approach to discussing a better known stream pollution ogre, called "Stream Classification." It is preferable to get this villain out in the open, where it can be examined in the clear light of day; conceivably, it may turn out not to be a villain at all.

Because of local conditions—most of Texas is high and dry—the state regulatory agency has not considered stream classification with any degree of enthusiasm insofar as stream classification means setting up an A, B, or C standard. However, if it is possible to call all streams Class A streams, and still consider that the streams are being classified, both the philologists and the technologists could be satisfied. On the other hand, if it is assumed that stream classification means that varying degrees of treatment will be required, depending on the receiving stream, a number of factors must be considered before the idea of stream classification should be embraced or discarded.

First, of course, is the use to be made of the streams. In Texas so much of the water has such high priority for domestic and irrigation purposes that practically none is left for diluting partially treated or untreated waste. High priority is also assigned to clean water for recreational purposes, such as fishing, boating, and swimming. In all fairness, however, it should be pointed out that in regard to swimming we are frequently accused of perpetrating an apparent inconsistency, because of our generally unfavorable attitude toward swimming in untreated surface waters.

Much argument has taken place over the position public health occupies in the stream pollution problem. Those who argue that only a very poor case, at best, can be worked up to show that polluted waters have been instrumental in spreading disease in recent years have a good point when considered on a direct basis. Isolated or infrequently reported cases of illness from drinking polluted water, by migratory workers, hunters, and fishermen, have been noted. Some illness has been traced to the consumption of raw oysters. Disease has in some instances been alleged to be due to swimming in polluted water. Although this certainly is not unimportant, it should be pointed out, for example, that an equally large area for public health effort exists in the field of poor plumbing, with resulting cross-connections, and poor water and sewer line construction. The most convincing public health argument against stream pollution is the intangible effect upon public health that is produced by the unrestricted availability of good clean water for drinking, cooking, bathing, washing, cleaning, flushing, etc.

The second factor to be considered —and this is not necessarily in order of importance—is the law under which a stream pollution enforcement agency must operate. Although the law may not represent the will of the people, it does represent the official will of the state. Therefore, it must be enforced as nearly as possible as intended by the legislature. Every area is a special case. If at all possible, the will of the majority should prevail; but regardless of the will of a local group, the first obligation of the enforcement agency is to the law. The enforcement agency must never forget its role as policeman and attempt to be additionally not only the law enforcer, but also judge and jury as well.

The Texas law is very explicit and has repeatedly been interpreted by the courts as preventing the placing into a stream of anything that will impair its usefulness for any of its beneficial purposes. Therefore, if Texas streams are to be classified at all they must all be Class A streams and all effluents entering them must be Class A effluents.

The third factor to be considered is the various pressure groups. Although these groups do not necessarily represent the people—or the law—they do have influence on both and must be heard. These groups cover a wide range, including sports, power, industry, irrigation, recreation, conservation, and others. Unfortunately, their proposed standards of achievement also cover a wide range, from "no treatment" to "no waste discharge."

It is apparent that this whole matter is a very complex one. After about 20 years of anti-stream pollution effort, I've concluded that attempting to solve the problem of stream standards *versus* effluent standards, on a nationwide or even on an area-wide basis, is not only hopeless, but also undesirable.

Roy F. Weston, Sanitary Engineer, Atlantic Refining Co., Philadelphia, Pa.:—Is there any particular place where streams have been classified or effluents have been classified, where there is a successful working program?

Mr. Herzik:—Frankly, I do not know of any, and that is one of the reasons we have more or less stayed away from the idea of stream classification in categories other than Class A streams. The U. S. Public Health Service has tried to persuade us to embrace stream classification but the general reaction in the Texas agency was one of waiting to be shown an effective application of the principle, meanwhile holding out for nothing but pure water in all Texas streams.

Mr. Weston:—Doesn't establishment of stream standards necessarily establish effluent standards?

Mr. Herzik:—That is why I combined the title of my discussion under the single designation "stream classification." One cannot be discussed without discussing the other.

Mr. Weston:—In all the discussion of the various technical ramifications of establishing stream standards and effluent standards, it is possible that not enough consideration is being given to the wishes of the public. Mr. Herzik has indicated that the public should have something to say here. New York State holds hearings where the affected segments of the public can determine what degree of treatment is to be provided for a particular stretch of stream. Even though we may not agree with the public's decision, it appears that as engineers we must solve the problem the way the public wants it solved, if that solution is economically feasible, rather than the way in which we, as a group of theoretical planners, may decide that it should be solved.

Mr. Herzik:—About 15 years ago an attempt was made to introduce into the Texas Legislature a law that would modify the present law and give the State Department of Health the privilege, or the duty, in effect, of classifying streams by setting hard and fast standards. Because the proposed bill wouldn't seriously interfere with enforcement of the law as practiced by the state agency, the agency went along with the bill. Unfortunately, the people of Texas didn't like the idea. Whatever the reason, enough pressure was placed on the Legislature to kill the proposed bill in Committee. Every year or two since then some type of pollution bill has been introduced into the State Legislature, but we have never been seriously threatened with a change in the law since about 1939. The major point involved is that the public is boss; if stream classification is wanted, that's what the public will get, but the present law will not permit anything to be put into any stream

—which limits the classifications that can be used.

Mr. Larkin:—There is one thing New York has in common with Texas—the public is the boss. There seems to be one great difference between New York and Texas, however, and that is that New York has lots of streams and lots of water. In New York, therefore, it is not necessary to classify all water for drinking use.

Mr. Herzik:—The major problems of getting necessary sewage treatment in Texas usually boil down to a legal question of who you are going to sue. Are you going to sue the Mayor? Suppose he resigns? Are you going to sue the City Commissioners? Suppose they all resign? Or suppose a bond issue is submitted to the voters, as required on all bond issues by Texas legislation, and is defeated? It is evident that there must be considerable reliance on education, preaching, begging, and other persuasive methods.

Unfortunately, when an industry is involved it can be taken to court because in that case the guilty party can be more definitely defined. It isn't a very fair arrangement, however, for industry. It must be admitted, nevertheless, that the legal cases involving stream pollution matters that have been won in Texas have been against industry. That does not mean that all industrial pollution matters are prosecuted in the courts, but simply that the cases actually won in legal proceedings have involved industrial pollution.

Leonard B. Dworsky, Senior Assistant Sanitary Engineer, USPHS, Washington, D. C.:—In some states, stream classification is done by the Legislature, through passage of a specific bill, although usually the actual classification is delegated to the administering agency. Apparently Texas actually has a classification scheme established by the Legislature, but in this particular case there is only one classification.

Mr. Watson:—The term "stream classification" means something different to practically everyone who hears it. When I think of stream classification, I think more or less of stream definition. That is the first thing that classification should mean. Before a regulatory agency can proceed with a sound program of pollution control, stream definition is necessary—whether it is called classification, definition, or by any other term. That is the starting point for investigating area by area and determining the degree of treatment required in the various industries discharging wastes to keep that stream in a condition necessary to serve the best interests of the local community or the state in which the particular area is located.

Mr. Herzik:—Better definition of terms would probably reveal less disagreement among the parties concerned with pollution control matters than is now apparent. In Texas there is one power plant that discharges hot water into the river. Under the term "impairment," that discharge is impairing water for swimming; but in terms of "pollution," it is not polluting the stream in the sense that the B.O.D. or the suspended solids content is changed. Unfortunately, in Texas when we go to court we quibble more about what pollution is, rather than whether there is pollution or not.

It is discouraging to work with an Assistant Attorney General on this type of case to the point where he understands what B.O.D. means and is just becoming conversant with the many other terms, only to have him replaced and have to begin all over again.

Mr. Dworsky:—The official policy of the USPHS has been, and continues to be, that the states determine such classification or non-classification as they desire, through whatever methods they desire to use. It is felt, however, that fundamentally classification is the kind of thing that takes place regardless of whether it's written in the statutes, written as an administrative

regulation by an administering agency, or, as in many cases, actually is applied merely because it is the basic method by which one arrives at the answer of how much treatment there must be for the particular waste. It makes no difference how the objective is arrived at; the important thing is that consideration be given to obtaining, to the best of our ability, the water use that will reflect the best public interest in the area concerned.

Mr. Jacobs:—In calling earlier in this discussion for broad, general objectives of water criteria, or water usage, it was not meant to imply that the control agency was going to throw out the window any thought of so many p.p.m. of this, or so many p.p.m. of that. Those yardsticks have to be carried along, even if only mentally. The only thing I'm against is having a regulation published which fixes such a value once and for all as being the limit that's going to be maintained. These standards, regardless of what they are called, should be used by the regulatory agency personnel to fix in their own minds, and in the minds of the people involved, what has to be done to that stream in order to improve it to the proper point. A stream may have too much B.O.D., or too much of this, or too much of that. But the requirement to be met should not be put out as an inviolate stream standard or effluent standard.

There hasn't been too much discussion here on stream standards and effluent standards as such. It is not generally realized, however, that industry pays a penalty in connection with an effluent standard because the control agency sets the standard of, say, 100 p.p.m. of B.O.D. in the effluent regardless of the volume involved. Now, the standard has been set to meet a summertime condition, when B.O.D. exerts its influence more rapidly, the dissolved oxygen drops more rapidly, and the 100-p.p.m. standard may be required to clear up that stream during warm weather. Most industries, however, use considerably less water in the wintertime than in the summer, but the control agency makes no distinction between summer and winter conditions. Therefore, the industries still must maintain less than 100 p.p.m. of B.O.D. in their effluents, which many times means at least 50 per cent improvement above what the stream actually requires. The stream under winter conditions can handle more total B.O.D., yet effluent standards would require that less be put in.

W. D. Hatfield, Superintendent, Decatur (Ill.) Sanitary District:—I happen to run a sewage treatment plant instead of a stream. Although there are a good many industries in Decatur, we have had an amazing experience in recent months.

Two large industries have come into the city, and in this case their effluents come to the sanitary district sewage treatment plant, rather than to the stream. One of the first things their engineers asked about was the limitations on what they could put into the sewers. I hemmed and hawed, told them there was no law as to concentrations, and that we were only interested in the total daily contribution of the various components.

They had just built a new plant in New Jersey, where they had worked under a rigid regulation that only allowed 100 p.p.m. of this and 100 p.p.m. of that. It was explained to them that we were interested in totals rather than concentrations—on the basis that 100 p.p.m. of oil in a small volume might not hurt us at all, but 10 p.p.m. of oil in a million gallons might be too much.

They also wanted a temperature regulation; that is, something on how hot the discharge to the sewer could be. The District attitude is to accept waste at any temperature as long as condensation problems don't arise in the pumping station. In that case, we simply require the offending industry

to cool its wastes enough to eliminate the trouble.

The crux of the matter was that they wanted definite standards to take back to their lawyers and management, so that five or six or more years from now they wouldn't have a change in requirements if my successor had some different ideas and wouldn't cooperate with them. I've attended many meetings, and the industrialists don't want standards; still, when it comes to the practical application, they insist on standards. They want a specific limit, because although they may be sure of regulatory action now, they want to be sure that 10 years from now someone else doesn't come in and change it. There are advantages in standards, but there also are disadvantages in standards. The standards should only be a guide to what we try to do, and not a limit.

John W. Wakefield, District Engineer, Florida State Board of Health, Jacksonville, Fla.:—Florida doesn't like classification either. The law says that no deleterious substance shall be discharged into the streams of the State of Florida. Obviously, the closest we can come to that condition is to treat each separate source of trouble as a separate case. We probably classify each stream mentally; we certainly classify the effluent mentally. But that is done without published standards, and on the basis of best use of the stream.

Professor Sawyer:—It may be of interest to relate one experience with industry in Massachusetts wherein effluent standards have been established, and the effluent standards are correlated with temperature conditions in the stream. During the hot summer months the B.O.D. of the effluent, including the cooling water used for diluting purposes, is established at 10 p.p.m. The effluent standards are on a sliding scale, however, so that under winter conditions B.O.D. as high as 65 p.p.m. is allowed in the effluent. That type of approach is what is really needed, rather than a fixed standard that must be met twelve months out of the year.

Chairman Bloodgood:—Is that a fixed standard?

Professor Sawyer:—It's a fixed standard, for that particular industry, based on the temperature of the water in the receiving stream.

Voice from the Floor:—Is it a stream standard or an effluent standard?

Professor Bloodgood:—It's simply an effluent standard tailored to meet stream standards.

Daniel A. Okun, Associate Professor of Sanitary Engineering, University of North Carolina, Chapel Hill, N. C.:—Effluent standards in parts per million can result in some absurd situations. For example, there are some industries with which I have had experience that use two water supplies—one for process water, and one for cooling water. The two sources happen to be about one-half mile removed from each other.

In one case, under the existing standards the waste cooling water presented no problem, but the process waste water was a little over the standards. So the two were simply mixed to meet the standards.

In another instance, the effluent standards could easily have been met by pumping stream water into the outfall just 2 ft. from the river bank.

As previously pointed out, the important item is not the concentration in the effluent, but the total quantity of any constituent involved. In other words, whether the total quantity allowed as a discharge to a stream is called a standard or a permissible load makes no difference; it should be based on the stream standard, not on the effluent standard.

James M. Brown, Jr., Sanitary Engineer, Lederle Laboratories, Pearl River, N. Y.:—To many, the word "standard" means, in effect, "fight." Actually, the important thing is the effect

that pollution will have on a stream. In other words, stream classification to conform with the best usage for the stream, as is being done in New York, seems much preferable to standards as such.

Chairman Bloodgood:—Several of the controversial questions regarding stream pollution and industrial wastes have again been rather thoroughly discussed. I had no hope of settling these questions when we started. I do feel, however, that this discussion has made it possible for a better understanding of the points of view of those who are not in agreement.

Progress in this direction has been slow. There seems to be general agreement, however, that there ought to be improvement in the conditions of the streams, that the public has a very important part to play in the determination of what the end result should be, and that the existing laws of the various states may at times impose severe restrictions on engineering decisions.

Whether progress in stream improvement matters is by a standard spelled with a capital "S" or by standards spelled with a small "s" doesn't seem to make a great deal of difference. It is important, however, that those who believe one way, and find out in five years that they were wrong, should be open-minded enough to admit that they were wrong, and by that time have corrected or made an effort to correct any steps they have taken in the wrong direction.

DRAINAGE FROM BITUMINOUS COAL MINES

Important facts uncovered during several years of research on the formation of acid mine water in bituminous coal mines are contained in a 37-page final summary report recently published by the sponsor, Bituminous Coal Research, Inc., in cooperation with West Virginia University. Issued as West Virginia University Engineering Experiment Station Research Bulletin No. 25, the report reaches the following conclusions:

1. The drainage water from some bituminous coal mines is acid in reaction and constitutes one type of industrial waste. The acidity is not due to the presence of free acid, but to certain sulfates in solution which hydrolyze in water to give an acid reaction.

2. The importance of this waste is geographically limited to certain parts of the bituminous coal area, the acid formation not being limited to the active life of a mine, but continuing after the mine is abandoned.

3. The most highly acid-forming seams studied have a high sulfur content in the roof strata, which become acid-forming after pillar robbing destroys the roof structure and exposes these upper strata to the air.

4. Acid formation in the mines is associated with the concurrent growth of iron-oxidizing and sulfur-oxidizing bacteria.

5. Fresh highly-acid mine water has a low pH and at this acidity ferrous iron is not appreciably oxidized by air or by dissolved oxygen. The ferrous iron is, nevertheless, oxidized to the ferric state by a bacterium present in the water.

6. Ferric sulfate, water, and finely divided pyrite react to form ferrous sulfate and sulfuric acid.

7. The factors responsible for acid formation are the presence of iron disulfide (pyrite or marcasite) in the coal and associated (usually roof) strata, the exposure of these materials to water and air by mining, the chemical oxidation of finely divided iron disulfides, and the action of bacteria in aiding the oxidation.

8. The products of oxidation responsible for the objectionable characteristics of acid mine drainage are principally sulfates of iron, aluminum, and manganese.

9. Research on potential control programs might be aimed at control of disposition of the iron disulfides, prevention of contact of iron disulfides with air and water simultaneously, reduction of bacterial activity, and removal of part of the objectionable impurities from acid mine water. Stripping operations are the most amenable to immediate treatment but constitute a minor portion of the problem.

10. No practical solution for the problem in general is yet known.

PAPER AND PULP WASTE REDUCTION BY MILL IMPROVEMENT *

By R. M. Drummond

Chief Chemist, Research Division, International Paper Co., Glens Falls, N. Y.

Experiences at the International Paper Company's Tonawanda Mill, in North Tonawanda, N. Y., covering plant improvements resulting in reduction in industrial waste from a particular mill, should be of interest. This mill, located at the north end of Tonawanda Island in the Niagara River, was constructed in 1924. It produces high-grade papers of the offset, book, tablet, cup stock, and coating raw stock types. It has a capacity of 205 tons of finished paper per day and its soda pulp mill produces an average of 105 tons of bleached pulp per day, which is used in the production of its own paper.

The equipment in the mill consists of two paper machines, each with wire widths of 208 in., and both practically identical in capacity and design. As stated before, there is also a soda pulp mill and bleaching plant. Operations are carried on over six 24-hr. days each week. Under full-time operation approximately 500 persons are employed.

One-half of the pulp requirements of the paper mill are manufactured from poplar wood in the mill's own pulp mill. The other half, principally bleached sulfite and bleached kraft stock, is manufactured at other mills of the company and shipped to Tonawanda. Other materials, such as alkali, clay, rosin size, alum, dyes, starch, etc., also are used in the production of the papers.

Two sources of water are employed; namely, the Niagara River and the city of North Tonawanda supply. Niagara River water is received through a shore intake located on the west side of Tonawanda Island, in the East Channel, and the average consumption is approximately 6.5 m.g.d. from this source. Of this, three-quarters is filtered through gravity and pressure rapid sand filters for mill process water supply, the untreated quarter being used for cooling, etc. Approximately 45,000 g.p.d. of city water are used for drinking and sanitary purposes.

The mill wastes all discharge to the Niagara River through two main outlets, one on the west side of the island into the main river channel, and one into the channel between Tonawanda Island and the mainland.

This mill, is a modern up-to-date plant. Built in 1924, it has been continuously modernized by the installation of new equipment. Since 1945, a total of approximately $1,500,000 has been expended on mill improvements and new equipment that has had a direct bearing on the amount of waste materials being sent by the mill to the Niagara River. The total tonnage now reclaimed, but formerly wasted, is 4,351 tons per year. In addition to this, 990 tons of calcium carbonate are no longered sewered, as was the practice in 1942.

Early Surveys

In the fall of 1948, the International Paper Company was asked to cooperate in the International Joint Commission Boundary Waters Pollution Investigation by providing data on wastes being discharged into the Niagara River by its two mills at Tonawanda and Niagara Falls. In the spring and summer of 1949, intensive surveys of both mills were carried out. In

* Presented at 1954 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 21–22, 1954.

April and September 1952, and as recently as December 1953, the waste data obtained in these surveys was brought up-to-date.

As part of the mill surveys, both water and material balances were prepared, the agreement obtained from month to month between the materials and water in and out of the process being remarkable and much beyond the original expectations. To get such agreement indicated that the data must be quite accurate. To obtain such information entailed considerable expense and work.

The company was requested by the International Joint Commission to provide the following:

1. Accurate data showing the volume and characteristics of the wastes discharged from principal plant sewers and check data on the discharge from minor sewers.
2. An indication of the fresh water used, both volume and locations.
3. An indication of white water reuse, both volume and locations.

In the surveys conducted in each mill, a general process flow sheet was prepared, as well as flow diagrams showing fresh-water and white-water use and mill waste and sanitary sewers. Fresh-water and white-water pumps were calibrated and weirs with level gages and automatic samplers were installed, wherever possible, in all sewers discharging wastes from the mill. This was done not only on the two main discharges from the mill, but also on the 10 minor discharge lines, six of which discharge west to the main river and four east into the channel between Tonawanda Island and the mainland. All were carefully measured and analyzed.

Paper Mill Improvements

Good water is essential to the manufacture of clean high-grade papers. Therefore, most mills sand filter their raw water, as in the case of the Tonawanda mill. Large volumes of water are used in the paper mill, so the reuse of as much as possible is essential This re-used water is normally called "white water."

In order to re-use paper machine white water, filter equipment is necessary. Each of the two paper machines in the Tonawanda mill is equipped with a vacuum-type save-all. Use of these save-alls, which take the excess rich white water from the paper machines and clarify it by filtering it through a mat of fiber, enables the mill to re-use this white water on the paper machine showers, etc., which are exclusively on white water, the volume amounting to 450,000 g.p.d. This use, in combination with use of the excess paper mill white water in the soda mill, has greatly reduced the total white-water losses from the mill and has also reduced the losses of white water from the paper mill to very low amounts.

The total losses of white water from the two paper machines for the months of July and August 1949 show an average of approximately 480 g.p.m. being sewered to the river. This is a total of 690,000 g.p.d. of white water.

The amount of water required for dilution of the stock in the head boxes of the two paper machines, for the average mill production, is 7.680 m.g.d. Therefore, if only 690,000 g.p.d. sewered, 91 per cent of the water used for head box dilution is re-used. Paper machine dilution is the main consumption of water in the mill, but other mill processes, such as the soda mill, also use a great deal of water. In the soda mill, paper mill white water can only be used on the bleached pulp, the unbleached pulp requiring fresh water. If one considers, therefore, that the total fresh-water consumption is only 6.435 m.g.d., the reuse of water in the mill can be appreciated. This re-use of white water is reflected in very low losses from the paper mill, which during the sur-

vey showed fiber and filler losses to be only 0.7 and 1.7 per cent, respectively, of the finished paper produced.

Other equipment installed in the paper mill since 1945 were six new screens, equipment to take care of the rejects or tailings from the screens, and four precision beaters. The tailings equipment replaced flat screens, which on occasions flooded, carrying fiber, filler, etc., to the sewers. The four new beaters replaced ten older type beaters, thus reducing by 60 per cent the number of beater units washed out on shutdowns. When washing these units, small quantities of fiber and filler, etc., are sent to the sewers.

All of this equipment, installed in the paper machines and beater room, saves fiber and filler, which have been estimated at a total of approximately 1 ton per day, showing a total saving in waste being sent to the river of 310 tons of fiber and 31 tons of filler per year. The reduction of 990 tons per year of calcium carbonate formerly discharged to the river is due to the discontinuance of the manufacture of calcium carbonate papers.

To further reduce paper mill losses, a larger save-all is being installed. This new save-all has twice the capacity of the present save-all units on the paper machines, hence will double the save-all capacity.

Soda Mill Improvements, 1945–9

The soda process, which is the cooking of wood with caustic soda, was the first method used to produce chemical pulp in this country, starting in 1854.

In both the soda and kraft processes the primary function is, of course, the production of pulp. Nevertheless, recovery of the alkali from the used cooking liquors is a requisite to efficient operation. This is accomplished in six steps. The first is the separation of the spent liquor, known in the industry as "black liquor" from the pulp. This liquor is then concentrated by evaporation to 50 to 60 per cent solids. In this form it is burned in a suitably designed furnace to generate steam and remove the organic matter, the molten sodium salts being withdrawn from the furnace and dissolved in water. Treatment of this solution of sodium carbonate with calcium hydroxide gives caustic soda and a precipitate of calcium carbonate. The caustic soda solution (white liquor) is separated from the calcium carbonate sludge and re-used for cooking. The carbonate sludge is washed and then calcined in a direct-fired kiln to calcium oxide, ready to be slaked and used again.

The pulp mill, built in 1924, has been completely renovated and all equipment installed of the latest design. This has greatly increased the efficiency of the recovery plant, which, of course, means much less alkali is being discharged to the sewer and consequently to the Niagara River. Equipment installed since 1945 includes the following.

Evaporators

One set of long-tube, vertical, quintuple-effect evaporators with capacity for concentrating all the black liquor from 125 tons of pulp daily. These replaced a set of 1924 quadruple-effect, horizontal-tube, evaporators with a capacity for handling the liquor from only 60 tons of pulp daily. The evaporators leaked badly, the entrainment in condensate was high, and all black liquor in excess of a 60-ton daily operating capacity had to be sewered. This at times amounted to as much as 5 tons of caustic combined with the lignin in the wood, which would be sewered daily.

Black Liquor Burning Equipment

One new modern black liquor burning unit has been installed. All the concentrated black liquor from the evaporators is sprayed into and burned in this furnace, which was designed for a capacity of 110 tons of poplar

soda pulp. This mill is normally run at an average production of 100 to 105 tons. Accordingly, there is ample capacity at all times in this unit. It burns the black liquor by the combustion of the carbonaceous ingredients in the liquor and a smelt consisting of approximately 99 per cent of Na_2CO_3 is tapped to a smelt tank, where it is dissolved, causticized, and the original caustic used in cooking is recovered to be used again for cooking purposes.

This unit replaced three rotary incinerators that formerly burned the liquor to about 80 per cent Na_2CO_3 and 20 per cent carbon. The carbon had to be settled and filtered out of this liquor and much of it was disposed of to the sewers.

Disc Evaporator

One disc evaporator has been installed to further concentrate the black liquor after leaving the evaporators. This serves the dual purpose of delivering a higher concentration of black liquor to the burner and it also picks up some of the carry-over from the furnace before going to the precipitator.

Precipitator

The precipitator is an electronic unit that removes 95 per cent of the solids from the gases leaving the furnace. Actually, recovers from 5 to 6 tons daily of soda ash and returns it to the system. This formerly was discharged to the atmosphere and some of it settled in the Niagara River. This unit, of course, was installed primarily to prevent air pollution rather than stream pollution.

Revamped Causticizing System

The lime slaking system has been revamped and modernized and now is capable of slaking all lime necessary for the causticizing of sodium carbonate (smelt from the furnace) for 110 tons of pulp daily. The former system was inefficient and difficult to operate, which resulted in spills of alkali to the sewers.

Soda Mill Improvements, 1949–53

The soda mill improvements previously outlined were made in the period 1945 to 1949 and were reported to the International Joint Commission at a hearing on November 15, 1949.

Since that time the following additional equipment has been installed.

Two-Stage Brown Stock Washing

The brown stock from the digesters was formerly washed on single-stage vacuum rotary filters to free it from cooking liquors. The new equipment now provides double washing, thereby lowering the alkali content of the filtrate now going to the sewers. It was anticipated that the two-stage washing would reduce the alkali as black liquor in the washed pulp by 0.5 per cent, or 10 lb. per ton. This has been realized, 10 lb. per ton on a production of 105 tons per day being 1,050 lb. per day less alkali being sewered.

Two-Stage Bleach Plant

In May 1952, a new two-stage bleach plant was put into operation. It included two new bleach stock washers to replace two 25-year-old units that had developed leaks in the filtrate lines and were responsible on occasions for some fiber going to the sewers. A definite saving of 2.5 tons of lime per day was realized due to the use of chlorine in the first bleaching stage. This amounts to 62 tons less per month of soluble solids in the main sewer.

Lime Kiln

In June 1952, a new lime kiln was put into operation. This kiln is equipped with a wet scrubber guaranteed by the manufacturer, to give 95 per cent recovery of lime. Realization of this recovery has reduced suspended and dissolved solids in the effluent from 119 tons per month, as in 1949, to 85 tons per month, a reduction of 34 tons per month.

Lime Mud Filter

At the same time a new lime mud filter was installed.

Foam Eliminator for Black Liquor Tanks

Another new unit started in October 1952 was a foam eliminator for the black liquor tanks. Its operation saves approximately 5 lb. of soda ash per ton, or 550 lb. per day (7 tons per month).

Concentrator for Black Liquor

A concentrator for black liquor was installed in June 1953 and should save 30 lb. of soda ash per ton of pulp, or approximately 42 tons of soda ash per month.

The new equipment for the soda mill, as outlined, is resulting in at least a saving of 16,500 lb. of alkali being sent to the river each operating day. This total is based on own mill cost records, which show that in 1945, 311 lb. of sodium carbonate makeup were required per ton of pulp, as compared with only 152 lb. per ton in 1952. This saving of 159 lb. per ton of pulp, on an average production of 105 tons per day for a 308-day working year, shows a total annual saving of 2,571 tons of alkali.

Since the installation of the new lime kiln and other subsidiary equipment the same is true of lime consumption. In 1945, the lime used per ton of pulp was 174 lb.; in 1953, 85 lb. per ton were used, a saving of 89 lb. per ton. On a production of 105 tons per day and a 308-day working year, the total saving is 1,439 tons of lime less going to the river each year. This means that the alkali and lime being sent to the river in 1949 has now been reduced by more than 50 per cent.

Summary

The modernization program carried out in the Tonawanda mill has contributed to a much lower discharge of waste, as shown by the following, as compared with the wastes discharged in 1942:

Item	Saving (tons/yr.)
Alkali	2,571
Lime	1,439
Fiber	310
Filler	1,021
Total	5,341

The cost of the equipment and changes to accomplish these results was $1,453,000.

Another item that should be mentioned is that in 1948 and previously a large quantity of froth was formed as the wastes entered the river. This froth was caused by the mixing of alkaline waters from the soda mill, containing carbonates, with the acid waters from the paper mill. Unsightly froth on the river was corrected by the use of foam killer.

In 1949, the pH of the soda mill discharge was 11.0, but a change in the system has now reduced the pH of this waste to 6.7.

No two paper mills are the same as regards the problem of industrial waste. The product manufactured, age and type of mill, and location, are all factors having a definite bearing on what can be done to reduce wastes.

As previously pointed out, the Tonawanda mill system is a closed one involving an integrated paper mill and bleached pulp mill. This is excellent as regards the re-use of white water, but it has its limitations. For example, the build-up of dissolved solids in the system can become so great that specifications for certain grades of paper cannot be met; hence, what can be done in wastes reduction depends on the product being made.

Great reductions in waste discharges can be made, however, by careful planning, constant control, and modernization through the use of new equipment, as described.

Stream Pollution

FUNGI IN POLLUTED WATER AND SEWAGE

II. Isolation Technique

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Preliminary experiments showed that fungi were present in polluted habitats, sometimes in considerable numbers. Studies were undertaken to survey several types of polluted habitats for their mold populations on a quantitative basis using techniques which could be duplicated readily.

In earlier work on aquatic fungi, Harvey (3) showed that few such fungi grew in polluted habitats. Using his technique, only a few so-called soil fungi developed. In 1944 Smith and Dawson (5) introduced rose bengal in a concentration of 70 p.p.m., or 1: 15,000, as an inhibitor for bacteria and actinomycetes in the glucose-nitrate-soil extract agar technique for the isolation of soil fungi. The dye was chosen in preference to boric acid as suggested by Tyner (7), or sulfuric acid as used by Waksman (8). Martin (4) modified the Smith-Dawson technique by applying it to the Waksman medium in a more dilute concentration, 35 p.p.m. or 1: 30,000, and adding 30 μg. of streptomycin per ml. of medium. As a basis for the quantitative study of pollution molds, an outline similar to that of Brierley *et al.* (1) was chosen.

Assay Sampling Technique

The Fairmount sewage treatment plant at Dayton, Ohio, was chosen as the source of samples for this series of tests. It was sampled at approximately monthly intervals. Material was obtained in 3-oz. soil cans. Preliminary oven-dry weights were run on the samples, which indicated a high water content in most cases. The treatment plant includes a number of processes through which the sewage materials pass before final discharge of liquids to the Great Miami River, or before preparation of sludge for sale as a soil conditioner. Samples were taken at 15 points throughout the plant from the effluent of the detritus tanks to the final effluent and dry sludge as follows:

1. Raw sewage after screening in detritus tanks.
2. Scum from Imhoff tanks.
3. Sludge from Imhoff tanks, held for 6 to 7 days at about 70° F.
4. Sludge from bottom of secondary digesters, held for about 45 days at 95° to 98° F. in essentially anaerobic conditions.
5. Effluent from Imhoff tanks at nozzles of trickling filters.
6. Scrapings from all sides of surface stone in high-rate filters.
7. Scrapings from all sides of surface stone in standard filters.
8. Effluent from high-rate filters.
9. Effluent from standard filters.
10. Material in distributor chambers.
11. Final plant effluent from channel to river.
12. Raw sludge one day to one week after pouring on sand drying beds.
13. Sludge on drying beds for about three weeks.

14. Air dry sludge ready for processing.

15. Heat dried sludge, pulverized and ready for sacking and sale as a soil conditioner.

In sampling soils, samples must be composited to eliminate bias from pockets of organisms developing under favorable conditions. In the work described here, at times both single and composite samples were used, apparently without difference.

Depth of sampling was governed by the material to be sampled. Scums, sludges, and liquids were sampled in such a way as to avoid taking any possible growths from pipe nozzles. Rock scrapings were made at random over the surface of the filter using a composite of scrapings from a number of stones and scraping all sides of each stone wherever organic matter had accumulated. In many cases it was obvious that mold growth occurred on either the upper or lower surface or, usually, on both.

Samples were returned to the laboratory and plated the same day as collected with one or two exceptions when they were stored overnight in a refrigerator. Because of lack of time and space, it was not possible to investigate the maximum period of time a sample could be stored without losing significant portions of the mold population.

Except for mid-winter freezing of drying sludge, no differences were noted in texture between samples collected from the same habitat throughout the year. In such a location temperatures are rather even. The temperature of raw sewage rarely fell below 60° F., or rose above 70° F., and that of the plant effluent varied little from those values.

Dilution

After briefly stirring with a spatula, 15-ml. portions were removed from the sample can by pouring or by lifting with the spatula, and placed in sterile 250-ml. Ehrlenmeyer flasks to which 150 ml. of distilled water had been added. Standing was permitted only long enough to work up the series of samples. The brief period of settling was counteracted by shaking by hand.

The 1:10 dilutions in flasks were placed on a rotary shaker and agitated at low speed (150 oscillations per minute) for 15 to 30 min. Five minutes are usually considered sufficient for shaking soil samples, but for sewage samples the longer period probably gave greater homogenization of the more viscid digester and scum samples, as well as the air and heat dried sludge samples.

Following the first shaking, 5 ml. of material were pipetted into 45 ml. of distilled water in another 250-ml. Ehrlenmeyer flask. This resulted in a 1:100 dilution and the process was repeated when 1:1,000 or 1:10,000 dilutions were required. Preliminary studies showed that a dilution of 1:100 was adequate for the more dilute samples with oven dry weights of less than 1 per cent, 1:1,000 for samples greater than 1 but less than 10 per cent, and 1:10,000 for samples with low water content.

Media

From the beginning of this study the Martin modification of the Waksman soil mold plate count agar was used primarily because of the results described by Martin (4) on the basis of a comparison of three types of medium using identical soil samples. In order to obtain greater efficiency a number of media were compared in eight series of experiments to determine a combination of nutrients, bacterial and mold colony size inhibitors, and antibiotics which would be suitable for general use.

Phloxine was compared with rose bengal as an inhibitor of bacteria and size of mold colonies. Four different concentrations of rose bengal were com-

pared without the use of antibiotics. Sabouraud's medium was compared with Martin's medium in three modifications. It was used with and without rose bengal, as well as with rose bengal and streptomycin. "Mycological agar" plain, with added salts, and with salts, rose bengal, and streptomycin, was tested in comparison with Martin's agar. Waksman's medium using two levels of acidity as bacterial inhibitors and Littman's oxgall agar were used. Conn's medium for the isolation of soil fungi was used plain and with added rose bengal and streptomycin. Glucose-nitrate-soil extract agar in which acidification and streptomycin were used as inhibitors, as well as the same medium in which rose bengal replaced acidification, were tested in comparison with the standard medium. Streptomycin sulfate was compared with aureomycin, terramycin, and chloromycetin as a bacterial inhibitor. "Mycological agar" was used a second time in comparison with "Mycophil agar." These were used plain and with added salts. In all four cases rose bengal and aureomycin were used. In this experiment Martin's agar was modified by substituting aureomycin for streptomycin and phytone for peptone. In four media described by Swaebly *et al.* (6), molar NaCl was used as a bacterial inhibitor. These media were compared with complementary media in which rose bengal and aureomycin were used in place of NaCl.

Preparation of Antibiotic

One gram of powdered antibiotic was emptied into sufficient sterile distilled water in an Ehrlenmeyer flask to give the equivalent of 1 g. of antibiotic in 150 ml. of water. This may be stored in the refrigerator. Of this solution 0.05 ml. was pipetted into 10 ml. of medium to give 35 μg. per ml. of medium, 0.1 ml. to give 70μg. per ml., and 0.15 ml. to give 105 μg. per ml.

Plating, Incubation, Counting

The basic medium required was prepared, poured in 10-ml. lots in culture tubes, and the tubes were capped, autoclaved, and stored in a hot-water bath at 40° to 45° C. After dilutions were prepared the warm tubes were removed from the water bath, the required amount of antibiotic in solution was pipetted into the medium, and 1 ml. of the diluted sample was added. The contents of the tube were then poured into 9-cm. Petri dishes and incubated. At first replicates of eight plates were used for each sample, but it was found that replicates of six were satisfactory for statistical analysis and this number was then adopted for routine work.

In the early stages an incubation period of three to five days was thought to be sufficient. However, when one group of plates was held for seven days a mold species was found to develop in quantity which had not appeared in the shorter interval. Thus, a maximum of seven days was chosen for the incubation period.

Room temperature was found to be adequate for incubation. In the winter this dropped to as low as 16° C. on several days, while at night and on weekends it probably reached a lower level. In the summer, room temperatures reached as high as 34° C. In the winter some species developed more slowly and in the summer most species had appeared at the end of five days. Depending on the temperature and humidity, at room temperatures 10 ml. of agar in a 9-cm. Petri plate may dry out more quickly in the summer than in the winter.

Colonies were counted at the end of the incubation period using a Quebec colony counter. The total number of colonies observed was recorded for each plate as well as the number of molds and, before antibiotics were used generally, the number of rhizobiaceous colonies. In addition, the number of colonies of each type of mold was recorded, together with the name or a

description of the colony so that information on the speciation of the habitat would be available. The mold and total counts could then be corrected to molds or organisms per ml. of original sample developed on a particular medium. This value could be corrected to an estimate of molds or organisms per gram dry weight of original sample.

Discussion

A number of media have been in use for the isolation of molds from substrata for some time. Aquatic fungi are trapped by the method described by Harvey (3), but only a few species of soil fungi can be obtained consistently by this technique. In preliminary work soil molds appeared to be predominant in polluted habitats so soil mold isolation techniques seemed to be best to use for general survey work. It was decided to test whether one or more of the commonly recommended media would be useful, or whether one of the recently developed techniques would be better.

Because phloxine differs from rose bengal (2) only in that in phloxine bromine replaces the iodine of rose bengal and there are two atoms of chlorine less, it was decided to compare the relative efficiency of these two dyes for the inhibition of bacteria and spreading mold colonies.

No reports have been found in the literature concerning the relative efficiency of different concentrations of rose bengal as a bacterial inhibitor or as a mold colony size restrictor. This dye, in concentrations of 1:5,000, 1:15,000, 1:30,000, and 1:45,000, was tested without antibiotics.

Sabouraud's medium is a popular medium for the isolation of fungi from various habitats. It is used most frequently in medical mycology and it was hoped it would act as a type of selector of pathogenic fungi. Sabouraud's medium contains no salts and has twice as much carbon and nitrogen source as Martin's.

The commercial preparation "Mycological agar" contains as much carbon source as nitrogen source by weight. The nitrogen source is soytone, a hydrolysate of soybean meal, rather than peptone, a hydrolysate of beef. Waksman's agar, as originally proposed for the enumeration of soil fungi, is based on the acidification, with sulfuric acid, of a medium with salts and half as much nitrogen as carbon source, for the reduction of the number of bacterial colonies. This should improve the ability of the worker to isolate fungi which have less competition and contamination. Littman's oxgall agar, in addition to the dye crystal violet, uses oxgall as a source of inhibition of bacterial colonies. Oxgall tends to reduce surface tension, and is thus inhibitory to certain organisms.

Conn's medium and the glucose-nitrate-soil extract medium were designed to do the same work as Waksman's medium. By the presence of potato starch in the former and soil extract in the latter, these media supposedly contained materials for improved fungus growth which by competition or acidification would restrict bacterial growth.

In the literature, Martin (4) was the only worker who had reported on the use of an antibiotic in the isolation of soil fungi. He used streptomycin, which was adequate for soils work. For the assay of the mold populations of large numbers of samples it was found best to have an immediately available supply of antibiotic on hand. It was thought best to have a broad-spectrum antibiotic that could be held in solution for a reasonably long period of time. Terramycin, aureomycin, and chloromycetin were compared with streptomycin at three levels of strength.

Throughout this work four batches of streptomycin, including both dihydrostreptomycin sulfate and streptomycin sulfate, and two batches of terra-

mycin HCl, were prepared and retained in the refrigerator for periods of up to two months. At the end of that time the solutions were still clear and their antibiotic effectivity, as indicated by total counts of plates, was apparently undiminished, although one lot of streptomycin was placed in solution after its expiration date. The lot of terramycin HCl used turned from golden to dark orange in color and after two weeks had developed a precipitate. Although it was still apparently effective in inhibiting bacteria, its use was discontinued. The lot of chloromycetin used never went completely into solution, which may account for its partial ineffectivity. Its use was discontinued because at the end of two weeks additional precipitate had formed, indicating instability in solution.

"Mycological agar" and "Mycophil agar," commercial preparations based on a nitrogen supply from soybean meal and other plant sources, were compared with Martin's medium in which phytone was substituted for peptone. To lots of each of the commercial preparations salts were added as in Martin's medium, and rose bengal and aureomycin were used in all five media.

Following the suggestion of Swaebly *et al.* (6), molar NaCl was tried in four media as a bacterial inhibitor. The same media were used in which rose bengal and aueromycin were used as the inhibitors of bacteria and reducers of mold colony size. This inhibitor has not been used in recent years, partly because better ones are available and partly because in the case of salt-tolerant species or strains no inhibition is expressed.

Results

Table I presents the results of the several tests of media, dye inhibitors, and antibiotics. A full description of the habitats was presented earlier and the formulations of the media are presented in the Appendix. Two sets of results are presented for each medium and for each sample. In each case the upper value gives the estimated average mold count, corrected to two significant digits, per gram dry weight of each sample. The lower value gives the ratio between the mold count and the total count. If the number of mold colonies is multiplied by the ratio, the estimated total count per gram dry weight can be obtained. The more efficient the medium for reduction of number of bacterial colonies, the closer to 1 will be the ratio value. If microorganism populations were the same in all samples, the ratios for each habitat would be similar. Not only is it apparent at first glance that each ratio and each mold count is different for each sample, but these also vary considerably between each medium used and each time the habitat was sampled throughout the summer, fall, and winter seasons.

When streptomycin was added with rose bengal to a dextrose-peptone-salts agar (Table I), it appeared that this medium was more efficient for the reduction of bacterial populations in all but one of the samples tested. Rose bengal alone was more efficient than phloxine alone. Phloxine was less effective in reducing the size of the colony of rapidly spreading molds than was rose bengal. On a phloxine medium, colonies were less distinct and not as readily identified as on rose bengal and its use was not continued.

It was found (Table Ia) that in all 12 samples tested a 1:45,000 concentration of rose bengal permitted most mold growth. In this concentration a large number of bacterial colonies were also permitted to develop, so that molds were not as easy to identify and picked colonies were more heavily contaminated. The 1:15,000 and 1:5,000 concentrations were inhibitory to both molds and bacteria. A concentration of 1:30,000 was used in ensuing work.

In the comparison of streptomycin, aureomycin, terramycin, and chloro-

TABLE I.—Effect of Dyes, Antibiotics, and Media on Development of Mold Populations[1]

Medium[2]	Habitat													
	1. Detritus Tank Effluent	2. Imhoff Tank Scum	3. Imhoff Tank Sludge	4. Secondary Digester Sludge	5. Imhoff Tank Effluent	6. Stone Scrapings, High-Rate Filter	7. Stone Scrapings, Standard Filter	8. Effluent, High-Rate Filter	9. Effluent, Standard Filter	10. Distributor	11. Plant Effluent	12. Sludge on Beds 1 Day to 1 Week	13. Sludge on Beds 3 Weeks	14. Air Dry Sludge
						(*a*) Dyes								
1.1	— —	71 16	180 27	140 6	210 10	360 18	230 19	100 23	63 11	140 9	90 74	22 21	7.9 28	37 100
1.2	— —	54 53	180 49	72 50	51 760	210 270	150 150	620 16	68 130	100 180	50 480	17 290	6.5 210	55 120
1.3	— —	59 110	170 110	82 170	86 1,200	190 680	190 680	560 62	100 260	130 400	50 700	17 120	6 720	110 95
2.1	— —	— —	210 160	72 380	110 1,100	1,150 130	670 230	110 700	270 68	200 62	95 790	85 160	24 530	2,600 77
2.2	— —	— —	190 4	70 2.6	140 3	1,100 5	650 7	— —	170 2.3	130 2.6	73 1.9	81 4.3	24 54	180 1.9
2.3	— —	— —	130 3.6	86 1.4	66 2.4	920 3.5	620 2	340 2	200 1.9	97 1.7	60 1.6	76 2.7	31 22	170 2.1
2.4	— —	— —	230 1.2	81 1.1	47 1.9	870 2.4	320 1.9	290 1.5	190 1.7	59 1.4	53 1.4	51 1.8	19 1.2	140 1.6
						(*b*) Antibiotics								
6.1[3]	190 88	120 100	66 120	14 3.1	86 270	840 180	390 520	180 10	690 2.5	310 11.1	33 135	54 100	40 211	3,300 47.4

[1] Upper value of each pair is the estimated total count of molds per gram dry weight of sample, in hundred thousands; lower value is the ratio between the molds and the total count.

[2] Medium designations correspond to formulas presented in Appendix.

[3] Collected and plated Feb. 12, 1953.

TABLE I.—*Continued*

Medium[3]	Habitat													
	1. Detritus Tank Effluent	2. Imhoff Tank Scum	3. Imhoff Tank Sludge	4. Secondary Digester Sludge	5. Imhoff Tank Effluent	6. Stone Scrapings, High-Rate Filter	7. Stone Scrapings, Standard Filter	8. Effluent, High-Rate Filter	9. Effluent, Standard Filter	10. Distributor	11. Plant Effluent	12. Sludge on Beds 1 Day to 1 Week	13. Sludge on Beds 3 Weeks	14. Air Dry Sludge
						(*b*) ANTIBIOTICS—*Continued*								
6.1[4]	94 6.5	190 100	85 130	29 25	70 340	480 160	4,400 73	55 61	38 130	84 150	90 23	8.8 350	40 1,800	2,900 16
6.2[3]	210 1.6	90 11	91 4.8	9 1	90 24	1,600 8.4	500 22	230 1.1	940 1	460 1.1	38 5.7	47 7.8	2,160 13	12,000 5
6.2[4]	160 6.2	180 4.7	190 5	38 2.4	98 27	440 7.6	5,700 1.4	83 3.3	70 6.3	110 5	58 3.5	13 5.7	48 126	6,500 1.2
6.3[3]	180 1.5	130 3.8	96 3.3	9 1	78 2.3	1,300 2	440 6.1	190 1	870 1.1	460 1.1	50 1	37 5.9	3,600 1	12,000 1
6.3[4]	180 1.8	— —	150 3	47 1.7	110 1.4	380 4.1	5,200 1.2	90 1.8	60 1.8	180 1.3	55 1.7	16 1.9	76 3	6,500 1.1
6.4[3]	190 1.5	100 4.8	110 3.1	9 1	39 5.3	1,400 1.4	440 3.1	190 1	880 1	450 1	25 2	26 5.5	2,900 1	12,000 1
6.4[4]	190 2	190 2.9	150 2.6	41 1.2	130 1.4	450 1.8	8,200 1.1	120 1.2	110 1.3	160 1.3	45 1.1	10 2.1	82 2.8	6,500 1.1
6.5[3]	170 70	100 24	63 43	9 1.5	140 83	1,200 2.2	750 67	260 1.5	1,000 1.1	480 2.7	38 19.7	51 12.3	1,200 76	9,800 10
6.5[4]	270 9	150 8.3	140 9.8	43 3.2	230 31	530 13	13,000 1.8	88 5.1	83 9.5	220 5.3	93 4.9	15 57.5	56 1,185	4,900 5.4
						(*c*) MEDIA VARIATIONS								
3.1	210 2.5	340 3.6	170 2.8	79 2.3	180 4	3,800 5.3	3,100 2.3	170 3.7	160 2.2	110 1.9	58 2.4	23 1.5	2,000 1.4	3,300 1.8

[4] Collected and plated Jan. 29, 1953.

TABLE I.—*Continued*

Medium[3]	Habitat													
	1. Detritus Tank Effluent	2. Imhoff Tank Scum	3. Imhoff Tank Sludge	4. Secondary Digester Sludge	5. Imhoff Tank Effluent	6. Stone Scrapings, High-Rate Filter	7. Stone Scrapings, Standard Filter	8. Effluent, High-Rate Filter	9. Effluent, Standard Filter	10. Distributor	11. Plant Effluent	12. Sludge on Beds 1 Day to 1 Week	13. Sludge on Beds 3 Weeks	14. Air Dry Sludge
						(*c*) MEDIA VARIATIONS—*Continued*								
3.2	90	99	140	110	90	420	360	160	75	97	48	27	2,500	2,600
	5,600	590	46	414	14,000	4,300	6,000	1,200	10,000	5,000	12,000	430	3.5	8.7
3.3	260	130	220	100	98	1,000	720	160	60	100	45	31	3,100	2,600
	1,700	520	210	320	2,800	1,700	26,000	38	3,200	1,800	333	160	12	5
3.4	290	320	300	100	130	3,300	2,400	290	200	170	85	33	5,000	5,200
	180	17	34	44	770	48	375	17	54	88	100	30	14	3.5
4.1	200	180	100	66	180	1,000	640	120	70	100	48	69	9.6	55
	4	5.4	5.7	1.9	4.3	4	6	3.2	4.1	4.3	6.6	5.3	12	7,200
4.2	43	170	140	44	59	820	600	90	25	70	43	49	6.5	2,000
	880	520	1,200	310	850	1,700	2,500	2,100	7,500	6,000	4,400	420	5,600	65
4.3	56	160	120	31	55	800	670	65	35	84	40	56	10	3,400
	7,600	760	640	100	1,100	1,900	1,900	3,900	5,400	3,800	6,300	800	4,800	39
4.4	200	210	210	42	160	1,400	950	130	90	160	83	93	10	6,500
	13	28	80	1,700	500	185	68	1,500	2,800	2,600	3,000	360	1,800	8.5
4.5	26	71	48	11	39	270	150	88	25	42	25	39	3.8	53,000
	?	?	?	?	?	?	?	?	?	?	?	?	?	?
4.6	190	900	220	51	660	8,500	6,300	220	170	300	250	400	48	33,000
	6.1	1	7.3	3.2	1.3	1.1	1	1.5	1.5	1.6	1.4	1	1.2	1
4.7	43	120	85	32	78	210	260	48	33	88	43	38	4.8	3,300
	1,600	42	76	6.5	100	4,200	294	14	1.8	21	29	52	6,200	5
5.1	100	150	250	18	110	1,600	680	110	50	510	620	48	18	15
	17	4.6	4	25	17	5	8	3.7	8.8	1	1	5.5	220	280

TABLE I.—*Continued*

Medium[a]	Habitat													
	1. Detritus Tank Effluent	2. Imhoff Tank Scum	3. Imhoff Tank Sludge	4. Secondary Digester Sludge	5. Imhoff Tank Effluent	6. Stone Scrapings, High-Rate Filter	7. Stone Scrapings, Standard Filter	8. Effluent, High-Rate Filter	9. Effluent, Standard Filter	10. Distributor	11. Plant Effluent	12. Sludge on Beds 1 Day to 1 Week	13. Sludge on Beds 3 Weeks	14. Air Dry Sludge
(*c*) MEDIA VARIATIONS—*Continued*														
5.2	26 15,000	67 650	130 790	18 250	110 3,300	280 7,800	170 12,000	95 260	43 5,900	180 700	110 440	20 5,600	5.3 1,200	15 11,000
5.3	39 1.1	33 7.1	33 10	0 0	98 1	240 5.4	140 8.9	120 1.6	30 3.5	700 1.1	1,100 1	15 4.8	6 2.1	0 0
5.4	29 1.4	74 1.5	120 1.2	21 ?	86 ?	530 1.5	330 2	110 1	65 ?	300 1	? ?	43 ?	13 ?	6.5 ?
5.5	77 930	130 6.5	240 8.1	25 5.1	140 380	1,400 125	810 31	130 4	70 14	570 1.2	670 1.3	76 6.5	25 21	26 53
7.1	88 2	150 3.2	86 2.3	16 1.1	39 1.3	230 2.9	130 3.3	33 1.1	25 1.3	97 1	38 1.3	19 6.7	2.9 1	3,300 1.1
7.2	140 2.4	220 2.8	170 1.7	18 1.6	86 1	630 7.6	500 11	70 1.4	75 1.5	84 1.5	55 1.1	54 3.9	5.8 1.4	4,900 1.2
7.3	130 2.7	220 2.3	140 2.1	16 1.5	86 1.1	590 6	540 1.1	50 1.6	50 1.4	93 1.2	60 1.3	53 3.8	6 1.3	5,900 1.2
7.4	240 2.1	220 2.6	150 2	23 1.3	55 1.3	540 13	670 6.8	58 2.2	70 1.1	100 1.4	60 1.5	59 6.7	4.8 1.4	9,800 1.3
7.5	220 2.4	220 2.5	190 2	34 1	70 1.3	910 5.1	680 12	75 1.6	80 1.2	150 1.5	75 1.0	59 5.9	6 1.1	20,000 1.4
8.1	58 1	17 1	38 1	9 1	39 1	340 1	0 0	25 1	125 1	0 0	25 1	—[b] —[b]	6.2 1	9.8 1
8.2	41 1.5	88 1.8	33 1.5	9 1	39 1	340 1.8	180 1	25 1	50 1	0 0	0 0	—[b] —[b]	12 1.1	3,900 1

[b] Not tested.

TABLE I.—*Continued*

Medium[a]	Habitat													
	1. Detritus Tank Effluent	2. Imhoff Tank Scum	3. Imhoff Tank Sludge	4. Secondary Digester Sludge	5. Imhoff Tank Effluent	6. Stone Scrapings, High-Rate Filter	7. Stone Scrapings, Standard Filter	8. Effluent, High-Rate Filter	9. Effluent, Standard Filter	10. Distributor	11. Plant Effluent	12. Sludge on Beds 1 Day to 1 Week	13. Sludge on Beds 3 Weeks	14. Air Dry Sludge
						(*c*) MEDIA VARIATIONS—*Continued*								
8.3	51 63	39 46	14 8.1	9 24	59 85	120 43	140 89	0 0	0 0	42 1	40 1	—[b] —[b]	2.4 1	59,000 1
8.4	220 1.8	120 2.8	90 1.3	18 1.2	78 1.7	900 2.9	730 2.1	33 1.2	45 1	55 1.5	25 1.6	—[b] —[b]	24 2.8	45,000 1
8.5	34 3.5	20 6.5	22 4.4	0 0	39 2.6	90 1.1	120 7.4	25 16	25 1	42 1	0 0	—[b] —[b]	4.3 3.7	85,000 1
8.6	136 2.2	130 3.4	96 2.6	14 1.3	66 2.4	910 4.4	690 25	33 1	25 1	84 1	70 1	—[b] —[b]	18 6.9	52,000 1
8.7	31 444	22 13	17 35	9 1.6	51 380	90 1,100	50 800	0 0	0 0	42 4	0 0	—[b] —[b]	3.1 20	85,000 1
8.8	240 3.7	87 4.9	96 3	14 1.1	200 31	1,200 4.8	1,300 10	33 1.8	50 2.1	50 2.3	30 3.5	—[b] —[b]	25 6.7	59,000 1

mycetin, at 35, 70 and 105 μg. per ml. of medium it was evident (Table Ib) from the results that regardless of the microbiota of the samples obtained on 2 different samplings 2 weeks apart, 35 μg. of antibiotic per ml. of medium was sufficient for bacterial inhibition. Terramycin and aureomycin, prepared at the same time, were about equally effective in reducing bacterial populations, although terramycin lacked stability. Streptomycin was much less effective than either terramycin or aureomycin, and chloromycetin was least effective. The use of rose bengal alone, as in the control for this sampling, is inadvisable unless antibiotics are not available.

Based on mold count alone, it appears (Table Ic) that a simple dextrose-peptone agar might be best for mold population development, especially when rose bengal and streptomycin are added to it. In all combinations in which a double-strength dextrose-peptone agar was used, larger numbers of bacteria appeared than when the strength of these ingredients was that of the Waksman type agar. The use of simple dextrose-peptone-salts medium was continued throughout the isolation work.

Waksman's agar, acidified below pH 4.1, was found to be useless (Table Ic) for the work. Bacterial colonies were of such a type as to be indistinguishable, when present. Waksman's agar, acidified to pH 4.1, permitted only certain species of molds to develop, whereas "Mycological Agar" and Martin's medium permitted a wider variety of species to develop. Littman's oxgall medium reduced the number of species of molds while permitting a larger number of bacteria to develop.

Conn's medium and glucose-nitrate-soil extract agar were found to be not as efficient, in varying degrees, as Martin's medium in the development of mold populations. Of the two, the glucose-nitrate soil extract agar with rose bengal and streptomycin appears to have some advantages, but neither are reproducible media.

The commercial preparations, "Mycological agar" and "Mycophil agar," gave results quite comparable with those of Martin's agar in which phytone was used instead of peptone. The addition of the same salts used in Martin's medium did not appreciably increase their efficiency. The use of rose bengal and aureomycin in all three types of medium is necessary for the best development of fungi and inhibition of bacteria.

Almost without exception, media containing 1.3 M NaCl proved to be less effective in inhibiting bacteria and mold colony size than those of the same composition but containing rose bengal and aureomycin as bacterial and mold colony size inhibitors. Using these two materials the N-Z-Amine-A casein hydrolysate medium and modified Martin's medium proved to be the best of the four media without NaCl, whereas the medium with added maltose was almost as good and the medium with inorganic nitrogen was poorest.

Conclusions and Recommendations

From the results of these experiments it appears that one of the more efficient media used throughout the series was Martin's medium in its original or a modified form. Other media were more efficient in permitting the growth of fungi, but failed in allowing large numbers of bacteria to develop. Most of the media tested allowed large mold colonies to develop, thus preventing the growth of other molds by competition. Mold species were inhibited by such substances as oxgall. Reproducible media appear to be preferable to non-reproducible media as developers of the mold populations of various substrates. Organic nitrogen nutrients appear to be preferred by molds and much better growth was obtained on organic nitrogen compounds

derived from soybean meal than those from beef. A casein hydrolysate medium seems to have good properties. Because aureomycin can be held in solution for periods up to two months and because it has the property of being able to screen out most of the bacteria present in a sample, its use in an isolation medium appears to be indicated. Although streptomycin appears to be adequate in soils work, other groups of bacteria present in polluted water and sewage samples are not affected by it. The use of inorganic mineral salts in culture media appears to be necessary in those cases where the organic nitrogen source is as low as 5 g. per liter and the carbon source, dextrose, is 10.

It is suggested that the medium used by Waksman, modified by Martin, and again modified by the Environmental Health Center laboratory, is a satisfactory medium for the isolation of fungi from polluted water and sewage samples. Its formula is as follows:

Dextrose-soy hydrolysate-mineral salts-rose bengal-aureomycin agar: Dextrose, 10 g.; phytone or soytone, 5 g.; KH_2PO_4, 1 g.; $MgSO_4$, 0.5 g.; agar, 20.0 g.; water, 1,000.0 ml.; rose bengal, 0.35 g.; and aureomycin HCl, 35 μg./ml. The commercial preparations "Mycological agar" and "Mycophil agar," as well as casein hydrolysate media, are also adequate for this work.

Acknowledgments

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APPENDIX—Formulas for Media Used in Experiments 1–8

1.1 Martin's modification of Waksman's medium for plate counts in the isolation of soil molds:

Dextrose ...	10.0 g.
Peptone	5.0 g.
KH_2PO_4 ...	1.0 g.
$MgSO_4$	0.5 g.
Agar	20.0 g.
Water .....1000.0 ml.	
Rose bengal.	0.035 g. (1 : 30,000)
Streptomycin	30.0 μg. per ml.

1.2 Same as 1.1 but without streptomycin.

1.3 Same as 1.2 but substitute phloxine in same concentration.

2.1 Same as 1.2 but rose bengal in concentration of 0.022 g. (1:45,000).

2.2 Same as 1.2 but rose bengal in concentration of 0.033 g. (1:30,000).

2.3 Same as 1.2 but rose bengal in concentration of 0.066 g. (1:15,000).

2.4 Same as 1.2 but rose bengal in concentration of 0.200 g. (1:5,000).

3.1 Same as 1.1.

3.2 Sabouraud's medium:

Dextrose ...	20.0 g.
Peptone	10.0 g.
Agar	20.0 g.
Water .....1000.0 ml.	

3.3 Same as 3.2 plus rose bengal 0.035 g.

3.4 Same as 3.3 plus streptomycin 30 μg. per ml.

4.1 Same as 1.1.

4.2 Mycological agar (Difco):

Dextrose ...	10.0 g.
Soytone	10.0 g.
Agar	35.0 g.
Water .....1000.0 ml.	

4.3 Same as 4.2 plus KH_2PO_4 1.0 g. and $MgSO_4$ 0.5 g.

4.4 Same as 4.3 plus rose bengal 0.035 g. and streptomycin 70 μg. per ml.

4.5 Same as 1.1 but instead of the addition of rose bengal and streptomycin the medium was acidified to a pH of 3.4 with sulfuric acid.

4.6 Same as 4.5 but acidified to pH 4.1 with sulfuric acid.

4.7 Littman's oxgall agar (Difco):

Dextrose ...	10.0 g.
Peptone	10.0 g.
Oxgall	15.0 g.
Agar	20.0 g.
Water .....1000.0 ml.	
Crystal violet	0.01 g.
Streptomycin	70.0 μg. per ml.

5.1 Same as 1.1.

5.2 Maltose .... 7.2 g.
Potato starch 10.0 g.
KNO_3 ..... 2.0 g.
$MgSO_4$ ..... 1.2 g.
KH_2PO_4 ... 2.7 g.
Agar ..... 15.0 g.
Water .....1000.0 g.

5.3 Same as 5.2 plus rose bengal 0.035 g. and streptomycin 70.0 μg. per ml.

5.4 Soil extract..1,000.0 ml.*

Dextrose ...	10.0 g.
$NaNO_3$	1.0 g.
K_2HPO_4 ...	1.0 g.
Agar	20.0 g.
Acidified with H_2SO_4 to pH 3.5	
Streptomycin	70.0 μg. per ml.

5.5 Same as 5.4 but instead of acidifying add rose bengal 0.035 g.

6.1 Same as 1.2.

6.2 a, b, c. Same as 6.1 plus streptomycin sulfate at 35, 70, and 105 μg. per ml.

6.3 a, b, c. Same as 6.1 plus terramycin HCl at 35, 70, and 105 μg. per ml.

6.4 a, b, c. Same as 6.1 plus aureomycin HCl at 35, 70, and 105 μg. per ml.

6.5 a, b, c. Same as 6.1 plus Chloromycetin at 35, 70, and 105 μg. per ml.

7.1 Same as 1.1 but substitute phytone (BBL) for peptone and aureomycin HCl for streptomycin sulfate at same concentrations.

7.2 Mycological agar (Difco). Same as 4.2 with additions as in 4.4, but substitute aureomycin for streptomycin.

7.3 Same as 7.2 with additions as in 4.3.

7.4 Mycophil agar (BBL). Same formula as 7.2, but phytone substituted for soytone with same additions.

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* Prepared by autoclaving 350 g. of soil in 750 ml. of water, filtering, and making up to 1,000.0 ml.

7.5 Same as 7.4 with additions as in 4.3.

8.1 KH_2PO_4 ... 1.0 g.
$NaNO_3$ .... 1.0 g.
Dextrose ... 15.0 g.
NaCl ..... 75.0 g.
Agar ..... 15.0 g.
Water .....1000.0 ml.

8.2 Same as 8.1 with substitution for NaCl as follows:

Rose bengal 0.035 g.
Aureomycin 35.0 μg. per ml.

8.3 K_2HPO_4 ... 1.0 g.
$MgSO_4$ .... 0.5 g.
Peptone ... 5.0 g.
Dextrose ... 10.0 g.
NaCl ..... 75.0 g.
Agar ..... 15.0 g.
Water .....1000.0 ml.

8.4 Same as 1.1.

8.5 KH_2PO_4 ... 1.0 g.
$MgSO_4$ .... 0.5 g.
Peptone .... 5.0 g.
Malt extract 5.0 g.
Dextrose ... 15.0 g.
NaCl ..... 75.0 g.
Agar ..... 15.0 g.
Water .....1000.0 ml.

8.6 Same as 8.5 but substitute for NaCl as in 8.2.

8.7 N-Z-Amine-A 50.0 g.
NaCl ..... 75.0 g.
Agar ..... 15.0 g.
Water .....1000.0 ml.

8.8 Same as 8.7 but substitute for NaCl as in 8.2.

USPHS REORGANIZES BUREAU OF STATE SERVICES

As part of an extensive reorganization of its Bureau of State Services, the U. S. Public Health Service recently announced consolidation of its 16 operating divisions under six divisions, three of which are new and three old. One old division, Administrative Management, has been abolished and its functions placed in another unit.

The three old divisions remaining untouched are the Communicable Disease Center, the Division of International Health, and the Division of Dental Public Health.

The three new divisions and the branch activities for which they now have responsibility are as follows:

1. Division of General Health Services.
   (a) State Grants.
   (b) Public Health Nursing.
   (c) Public Health Education.
   (d) National Office of Vital Statistics.
   (e) Arctic Health Research Center.
2. Division of Special Health Services.
   (a) Chronic Disease and Tuberculosis.
   (b) Venereal Disease Control.
   (c) Occupational Health.
3. Division of Sanitary Engineering Services.
   (a) Water Pollution Control.
   (b) Sanitation.
   (c) Engineering Resources.
   (d) Sanitary Engineering Center.

The Sanitary Engineering Center has replaced the title and functions of the former Environmental Health Center, with its primary facilities located at the Sanitary Engineering Center Building at Cincinnati, Ohio (see THIS JOURNAL, **26**, 4, 549; Apr., 1954).

The reorganization is expected to more effectively group a variety of professional skills and related program functions which will facilitate a more comprehensive and unified attack on basic public health problems.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

1953 OPERATORS' FORUM *

M. E. DAWKINS, *Leader*

Sanitary Engineer, Bureau of Sanitary Engineering, Florida State Board of Health, Jacksonville, Fla.

Chairman Dawkins:—As has so successfully been done in past years, this forum has been programmed on only a few topics of general interest to operational personnel. The topics listed are not necessarily those of greatest interest, or in the order of interest, but they have been chosen because during the past year they seemed to be the principal subjects of discussion among operators all over the country.

Manpower Requirements for Operation

Edwin B. Cobb, Partner, Metcalf and Eddy, Consulting Engineers, Boston, Mass.:—These remarks regarding the manpower requirements for sewage treatment plants are from the viewpoint of the designer of treatment plants. Many designers do not have an opportunity to supervise the operation of sewage treatment plants, and generally must obtain their knowledge of personnel requirements second-hand, and by observation. This lack of actual contact with the personnel problems on the part of some designers can lead to unhappy conditions for the operating force. Such designers should recognize their limitations and make the best analysis possible of the personnel requirements. A designer with actual operating experience is a valuable asset.

The number of persons required to operate a sewage treatment plant is dependent upon several factors, the more important being the following:

1. The size of the plant and the nature of the treatment process.
2. The amount of mechanical or labor-saving devices provided.
3. The efficiency of the personnel available.
4. The funds available.
5. The extent to which good operation, good housekeeping, and good maintenance are practiced.
6. The length of the work week and union requirements.

Sewage treatment plants come in a vast range of sizes and in a great variety of facilities. In New England there are a number of small plants which have only a limited amount of mechanical equipment and at which sludge is dewatered on sludge beds. At such plants one man daytimes, with occasional outside help to clean the sludge beds, comprises the operating staff. On the other hand, the operating staff of the Chicago Southwest plant is said to exceed 500.

* From transcript, 26th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Miami, Fla.; Oct. 13–16, 1953. [The remainder of the Forum discussion will appear in an early issue.—Ed.]

In small municipalities where the operating budget is apt to be limited, our office has favored the Imhoff tank for primary treatment and the trickling filter followed by settling for secondary treatment. Such facilities often can be operated by a crew of not more than one or two men. At plants equipped with heated sludge digestion tanks and involving an appreciable amount of mechanical equipment, it may be of benefit to employ vacuum filters for sludge dewatering because of the type of personnel required to operate the filters. Filter operators are often good mechanics; therefore, if the filters are oversized so as to require only limited operation, the filter operators are available for mechanical maintenance work during their spare time.

In the choice of manually-cleaned *versus* mechanically-cleaned racks, or communitors; mechanically-cleaned *versus* manually-cleaned grit chambers; manual skimmers *versus* mechanical skimmers for sedimentation tanks; etc., the designer should give careful consideration to the effect of such equipment on the size of the operating staff. Under some circumstances, a manually-cleaned rack may require such frequent cleaning as to monopolize the services of one man and possibly require around-the-clock attention. On the other hand, provision at an automatic sewage pumping station of a manually-cleaned rack which must be cleaned at least once a day, may ensure at least daily inspection of the pumping equipment.

In the landscaping of plant grounds, the designer should be careful in his planning of lawns and planted areas not to make necessary an undue maintenance force to keep the grounds presentable.

Unquestionably, the type of personnel available to the treatment plant is very important. One bright, energetic, reliable young worker is probably worth several who are physically unfit or incompetent. However, due to tight labor conditions, a plant superintendent may have to accept the latter or have no help at all.

Frequently there is a ceiling on the funds available for the hire of sewage treatment plant personnel and too often the ceiling is much too low. If adequate funds are not forthcoming, the plant staff must be cut to fit what is available and operation struggles along.

At many plants, especially the larger ones, the number of maintenance personnel may equal the total operating personnel. An adequate number of maintenance workers is necessary if plant housekeeping and maintenance are to be kept up to top standards. Poor housekeeping and maintenance may permit lower operating budgets for a limited period, but at some future date there is usually a day of reckoning, often an expensive one.

When a plant is placed on a 40-hr. work week, each round-the-clock watch position requires the equivalent of about 4½ men to provide relief operators and for vacation and sick leave requirements. In some instances, also, union requirements, such as those covering switchboard operators, crane operators, etc., have caused personnel problems. These conditions vary from plant to plant.

Although the designer may not have control over most of the factors determining the size of the plant staff, there are some things he should observe. These are listed briefly as follows:

1. He should keep the operation of the plant simple, convenient, and along proven lines. Each operation should be carefully analyzed to determine its effect on the over-all plant operation. Dangerous locations, undue climbing, or inaccessible facilities should be avoided.

2. In selecting automatic or labor-saving devices he should make sure that

the maintenance and adjustment of such items does not exceed the labor they are intended to save.

3. Operating personnel should be provided with conveniently located toilet, washroom, lockerroom, and lunchroom facilities, all of a type which can be easily cleaned, ventilated, lighted, and heated.

4. Scattered operations requiring considerable travel between stations should be avoided. Outdoor operations in northern climates can be especially difficult in cold weather.

These remarks perhaps are not very specific, but it is difficult to be specific with such a diverse field as sewage treatment.

P. A. Seager, Superintendent, Sewage Treatment Plant, Winter Haven, Fla.:—In a one-man plant—that is, where the lone operator is on duty seven days a week, 52 weeks a year—it is seldom that anyone is available to replace the operator for vacations or emergencies. From that standpoint, as well as from the standpoint of safety, what should be done to provide relief?

Mr. Cobb:—A lot, of course, depends on the type of plant. Generally, two men are better than one. If it's a real small plant, maybe that could be accomplished by having, say the water superintendent have over-all charge of it, and have another man act as operator. At least there'd be a second man looking in on the operator once in a while. It is not desirable to have one man alone in a plant, but if the plant is real small maybe that's the best that can be done.

Paul W. Reed, USPHS, Chicago, Ill.:—In 1951 the Sanitary Engineering Division of the Indiana State Board of Health sent out a questionnaire to sewage treatment plant operators regarding manpower requirements. A summary of the replies has been published (see THIS JOURNAL, **24**, 1, 93; Jan., 1952). In general, primary treatment plants for populations of 2,000 to 14,000 required one man, although in many cases it was felt that a full day was not required even for that one man. Trickling filter plant operators, from 700 to 5,000 population, also required about the same time—2 hr. to a full day. In the 20,000 to 55,000 population bracket, trickling filter plants required 6 to 9 men, based on a 40-hr. week. Activated sludge plants serving 5,000 to 12,000 required 4 to 7 employees; 35,000 to 41,000, 10 to 16 employees; and 65,000 to 200,000, 23 to 29 employees. One of the factors that affected the manpower requirement was the method of sludge handling. In one city of 4,000 population where the sludge is hauled in liquid form, 30 per cent of the operating time is spent in handling sludge. In another plant, serving 65,000, taking care of sludge requires 21 per cent of the total operating time. In some plants this factor is as low as 4 or 5 per cent. Most of the lower percentages, however, were due to allowing the public to come in and take the sludge off the beds.

A. C. Bryan, Superintendent of Sewage Treatment, Houston, Tex.:—From where does the legend stem that an activated sludge plant implies more manpower, as compared with a plant using any of the other conventional secondary processes? Additional labor has to be furnished, of course, and operation watched closely for a while. We fail to see, however, where the activated sludge plants need a bit more attention than the trickling filter or the Hays process plants.

This experience is mentioned because so many designers often avoid activated sludge for small plants, being sold on the idea that additional personnel or more technically trained personnel are required. I'm speaking from a relative point of view from one type of process to another; not from degree of treatment desired as an optimum.

The question arises because of recent

experience at Houston, where a sudden expansion of the city limits suddenly thrust on the municipal department responsibility for about a dozen small suburban treatment plants that had been built by developers or other political subdivisions. The plants were of varying qualities of construction and many varieties of treatment, including activated sludge, Hays process, standard-rate filters, and high-rate filters. Up to that time the city had been operating only the two large treatment plants.

The new plants were classified as pumping operations and assigned to the pumping station personnel for attention on their daily rounds. The pumping station operators, incidentally, were given training in the rudiments of treatment.

W. W. Mathews, Superintendent, Gary (Ind.) Sanitary District:—All of us have seen small plants run on a part-time basis by one man that were doing better jobs than large plants employing many people. The answer seems to depend on how good a job is desired. Even a fairly large plant can be run by one person over short periods, but maintenance and other considerations require more people.

At Gary we never have enough personnel. In fact, I have yet to see a sewage treatment plant anywhere in Indiana where anybody is standing around anytime doing nothing—especially, those below the technician's classification.

Of course, the superintendent never has anything to do. I run errands in my plant because I can't afford to send a mechanic—it would slow down the job. But I can drive downtown and back, a 10-mi. round trip, without slowing anything down.

Philip F. Morgan, Professor of Sanitary Engineering, State University of Iowa, Iowa City, Iowa:—In St. Louis there are at least two firms that provide operating supervision. Last summer I had an opportunity to observe the method of operation of one firm at a small activated sludge plant in the St. Louis area. This firm supervises some 30 plants; the other has a smaller number.

A car drove up with two men; one was the operator, the other a laborer. The laborer immediately started washing down; the operator took a sample for D.O. analysis, entered the data, and at the end of an hour they were ready to leave. Then I talked to them.

The plant was clean. The control building was just as clean as any building that has excellent maintenance. But the difference was that those two men were on a set schedule. They did their job, but that plant had been designed specifically with that type of operation in mind. Many of the problems of operation have been eliminated by designing for the operator, not just for the processing. Many others have been minimized by having an operator that will do the work.

This same two-man crew services a series of plants of various types—trickling filters, activated sludge—and the time is about the same for all of them. They make their rounds daily.

Gordon E. Mau, Chief, Water Pollution Control Section, Kansas State Board of Health, Lawrence, Kans.:—There are too many favorable comments on this matter of activated sludge plants in small communities. As to whether or not they take more operation, an activated sludge plant should have nearly constant attendance, just in case. If you only get one electrical failure a year, it may put the plant out of operation for two weeks. Are you willing to take the chance of sacrificing treatment for two weeks?

J. S. Whitney, Chief Operator, Dade County Port Authority, Miami Springs, Fla.:—Should small plants be designed to operate with minor attention or to perform the job they are intended to do? How can an operator run a 30-min. settling test and determine D.O.,

chlorine demand of the sewage, chlorine residual of the effluent, along with other information required by the State Board of Health, in two hours a day? Even if he can do these things, he wouldn't have time for the other necessary work. Wouldn't it be better to educate those responsible for buying the plants to the need for adequate trained personnel to accomplish the required results?

Mr. Cobb:—To merely take the recommendations of the manufacturer and pass them along to the client is not design. The equipment manufacturer, of course, would tend to play down the amount of labor needed to operate his particular process. It is up to the designer to analyze those things for himself and reach his own conclusions as to the amount of labor required for any particular operation.

As to the time required for operation, the following will serve as an example of our thinking. We recently completed, for a small New Hampshire resort town, a plant consisting of a main pumping station, an Imhoff tank, a standard-rate trickling filter, and a final settling tank with chlorination. For operating that plant we proposed that the water superintendent have control over both the water and sewage system and that he be provided with a labor-type operator to push the buttons at the plant, clean the sludge bed, and do the various things from day to day. The operator is to be present at the plant five days a week, eight hours a day. And on Saturdays and Sundays the superintendent and the operator will each put in an hour or so at the plant to see that things are operating as they should be. That's about all that very small town can stand in the way of operating personnel.

T. R. Haseltine, Partner, The Chester Engineers, Pittsburgh, Pa.:—The manpower requirement of any type of plant hinges to a great extent on the amount of laboratory work that is done. It takes just as long to make laboratory tests for a 0.5-m.g.d. plant as for a 10-m.g.d. plant. In a trickling filter plant laboratory control may be designed to set up records so the State Board of Health will know how the plant is operating, or for the community's use in the event of a law case, or for actual operation of the plant.

I don't see that laboratory control helps one bit in the operation of an Imhoff tank-standard trickling filter plant. All the records needed may be established in the matter of an hour or so. But in an activated sludge plant there are things that can be done to economize in power consumption, for instance, by laboratory control. In a small plant however, it is possible that the time required for making the laboratory tests will cost more than the power saved.

Much depends on the design of an activated sludge plant that is to be operated without laboratory control. Not only must the design be extremely conservative, but the load also must be very uniform. Many small plants handle milk receiving station or other wastes that produce a variable load on them. I don't believe that a small activated sludge plant or one with a highly variable load can be successfully operated without laboratory control.

Mr. Dawkins:—The Ohio Association has been conducting a survey on manpower requirements, salary scales, etc. Although the survey is not yet complete, a preliminary report, at least on the method of the survey, may be of interest.

T. C. Schaetzle, Superintendent, Sewage Treatment Plant, Akron, Ohio:—The industrial waste group of the Ohio Sewage and Industrial Wastes Treatment Conference is very active. Perhaps this is because the President of the Conference is himself a member of industry.

The program mentioned was set up not only to study salaries, but also to

try to create an awareness for the need of securing and retaining competent personnel at sewage treatment works and industrial wastes plants, the thought being that if people are made mindful of the need of such personnel, the matter of salaries will follow. In the Ohio study, qualifications were set up for supervisory personnel from the superintendent down to the laboratory technician, but not below that level. The latter limit was set to prevent the survey from becoming too comprehensive for practical use.

Competent personnel will not be secured or retained at sewage treatment works unless the thing that interests the individual—namely, the salary—is made attractive. There is little hope of attracting young engineers into the sewage or industrial wastes treatment field when, even without experience, they can get $4,500 to $4,800 in industry and the salary of the superintendent of a treatment plant serving a population of 200,000 to 250,000 is only in order of $6,500 to $7,000.

With the data at hand concerning the qualifications required and the salaries paid throughout Ohio at various sized plants, the industrial representative on the survey committee has agreed to review all of these jobs, with their salaries, and set up a tabulation showing the salaries paid in industry for like positions. In that way it is hoped to bring to the public's attention the discrepancy existing between industrial workers and those in the sewage treatment field.

One of the biggest matters of concern is that young men are not being attracted to this field. For the good of the profession, I would like to see a nation-wide movement to try to raise the status of sewage treatment personnel. We feel in Ohio that the guidance of the industrial men is very apt, and will bear fruit. There's not much more that can be said at this time, except to urge that each of the states try to do something to raise the standards of the operating personnel at sewage treatment works. What the Ohio Conference is doing may not be ideal; but it is a start, and it is hoped that by the time of the Federation's 1954 meeting in Cincinnati the results of the survey will be available.

Training Programs for Plant Personnel

W. T. Linton, Executive Director, South Carolina Water Pollution Control Board, Columbia, S. C.:—The question of training operators in waste treatment plants has long confronted the interested agencies as a problem of outstanding urgency and importance. Much has been said about the problems, but generally little has been done to fulfill the need for formalized training in this field.

In South Carolina we have long felt the need for more formal training of water and sewage plant operators than can be presented during an annual short school of not more than three-day duration. (The short school referred to is conducted by the South Carolina Water and Sewage Works Association in cooperation with Clemson College.) This need has been partially satisfied by a program of correspondence course instruction conducted since 1951 by the faculty of Clemson College under funds appropriated by the State Legislature as part of the annual budget of the state-supported institution.

Because there are presently four grades of operators in South Carolina defined under a voluntary certification program administered by the South Carolina Water and Sewage Works Association and the State Board of Health, it is necessary to prepare separate courses for each class of operator. Therefore, beginning in 1951–2 Clemson College published and distributed correspondence courses for Class D operators (lowest class) and for Class C operators. During 1953–4 courses are being prepared for Class B, and in

1954–5 courses will be published for Class A operators and administration of water and sewage facilities. Although administration of the courses is under the supervision of a committee appointed by the President of Clemson College, and the individual lessons and examinations are distributed, collected, and corrected by the College, the matter of certification of the operator as qualified under the classes listed is still the responsibility of the Certification Committee of the South Carolina Water and Sewage Works Association.

Since the program is a joint undertaking by Clemson College, the South Carolina Water and Sewage Works Association, and the South Carolina State Board of Health—and is financially supported by the State—it has so far been possible to furnish to all Association members who wish to take the courses a complete series of lessons in either water or sewage treatment without cost in any amount above his yearly membership dues in the Association.

The courses usually are arranged to contain from 16 to 24 lessons, which allows slightly more than two weeks for each lesson to be prepared, questions answered, and returned to Clemson for correction and the next lesson sent to the applicant. The lessons usually contain some 12 to 30 pages, single spaced, mimeographed on one side, and each deals with a specific subject. It is hoped that this procedure will create the reading habit, thereby accomplishing more than the obvious objective.

Keeping the subject matter at a level which can be of help to all the plant personnel in the state is a major undertaking. To assist the College in this matter, the Association has appointed a School Committee, whose function it is to cooperate with the College Committee in forming outlines upon which the course preparation is based. In addition to these important duties the Association's School Committee assists in the actual preparation of such subjects as it feels can be done by Association members for inclusion in the courses.

Glen O. Fortney, Division of Sanitary Engineering, State Department of Health, Charleston, W. Va.:—Just what type of material is presented in these correspondence courses?

Mr. Linton:—Information contained in these courses at the present levels—Grades D and C, the lowest and the next higher—is of a very elementary nature and is prepared so as to insure that the people who are served by it will not be overshot. Each course is prepared on an outline submitted to the School Committee of the Water and Sewage Works Association, which in turn controls the level at which entries will be made. Mathematics is an integral part of each of the two courses already prepared. When we get into the B and A classifications, we expect to proceed to graduate-type instruction, but because many of the operators in the state have not completed high school the first two courses are very elementary.

Mr. Fortney:—Do those completing the course receive a certificate?

Mr. Linton:—They receive a certificate from the South Carolina Water and Sewage Works Association. This certificate has on it, rather prominently, the words "Clemson College," and is signed by the President of that institution. He was among the first to recognize the need of such instruction, and we feel that the psychological result of having him sign the certificate would prove a stimulus to successful continuation of this type of instruction.

H. E. Orford, Acting Chairman, Department of Sanitation, Rutgers University, New Brunswick, N. J.:—Is this correspondence course going to supplant the three-day short course or to supplement it?

Mr. Linton:—The correspondence course will supplement the three-day

short courses, which will continue. Following the issuance of the Grade B certificates in 1952 it has been ruled, as a matter of policy, that any subsequent certificates issued by the Association must be earned by satisfactory completion of an examination stood at the college.

Mr. Fortney:—Are any text books used in connection with the courses, or is all the course material on the outline sheets sent to the students?

Mr. Linton:—Of necessity, the material submitted is in loose-leaf form. Each lesson varies from 16 to 54 pages of single-spaced mimeographed sheets. The latter part of that, of course, is the bibliography of material, which is utilized. We have been confronted with quite a problem in reproducing certain pictures or demonstrations in connection with this course. Incidentally, I failed to mention that the title as it appears in the Legislature's appropriation is, "Teaching and Research in Water and Sewage." The inception of this idea indicated that there was a need for a non-regulatory spot where operators would have an opportunity to better equip themselves for their jobs.

F. W. Jones, Partner, Havens and Emerson, Cleveland, Ohio:—There seems to be a tendency to make some of these courses too hard. After all, the great majority of treatment plants is of the so-called one-man type. Mr. Linton mentioned that mathematics was included in the South Carolina courses. That's fine, but I doubt that many of the operators use mathematics in their plants.

Someone else has mentioned records, either for designing or for the State Health Department. Noone believes more in records than I do, but have you ever analyzed some of the printed reports and tried to make them talk? They lie, because they don't tell the same story twice. How many operators look at their suspended solids values and picture a heap of sludge? But try to turn the suspended solids into sludge, and you find a wide discrepancy. Or, by the same token, to take the sludge data and try to convert it into suspended solids removed sometimes gives astounding figures. We should either make fewer records, or learn what to do with those we have. Certainly, a good many of the records that are published now aren't worth much when you come to analyze them. Let's get down to fundamentals and teach the small plant operators fundamentals.

Mr. Bryan:—It is gratifying to learn that some of our co-workers are including mathematics in their instruction to the lower level operators. Texas doesn't use the correspondence course method, but does have an itinerant instruction method, sponsored by Texas A & M College, whereby the instructor travels to the various parts of the state and conducts regional schools.

In 1952 the group in my area requested a 20-hr., two-week course on mathematics. Whereas registration for courses on the more common topics is usually in the neighborhood of 25 to 30, announcement of the mathematics course drew a preliminary registration of 70. By about the third meeting night, attendance was close to 100, and at the end of the two-week instruction period the group in attendance requested the instructor to continue for another week. It must be remembered that these men had driven quite a distance each evening after a full day's work to attend a 3- to 3½-hr. session on mathematics. Certainly that is some indication as to whether or not mathematics should be included in the instruction.

Ralph Hoot, Chief, Sewage Treatment Section, City of Philadelphia, Pa.:—After some experience with training programs in water treatment plants, it was only natural that I continue with the same type of program when I took over the Fort Wayne, Ind., sewage treatment plant in 1940. As a major part of that program I com-

piled a 200-page book on "Operating Procedures," which not only told what to do in the plant, but also why it was done. The content was directed both at the men in the laboratories and at the men in the plant.

Now that I'm in Philadelphia, where one new plant has recently been placed in operation and two more are being built, I'm going through the same old program of training men, which also means writing another "Operating Procedures" book. In this case the book probably will run to 400 or 500 pages. It's currently about 60 per cent complete, most of the work on it being done outside regular working hours.

Mr Dawkins:—I take it that you would suggest a separate, written, operation guide for each treatment plant.

Mr. Hoot:—That certainly would be very desirable. In the "Operating Procedures" book for Philadelphia there is a separate section for each unit. Each section concludes with a series of questions and answers. Most of the questions require mathematical answers. In the few weeks that have elapsed since the finished sections were distributed, two of my men have already signed up for correspondence courses.

George T. Lohmeyer, Superintendent, Sewage Treatment Plant, University of Florida, Gainesville, Fla.:—The General Extension Division of the University of Florida recently conducted a state-wide survey of water and sewage plant operators, asking them to rank the subjects that they would desire to have in short courses. Briefly, the results showed that the fundamental courses, such as basic chemistry and basic mathematics, were exactly what they wanted. Since then the correspondence course on basic mathematics for water and sewage plant operators has been written. A number of operators throughout the state are now enrolled in that course, although no operator has yet completed it.

Mr. Seager:—Florida, of course, has an annual five-day short course, with examinations on the sixth day, put on at the University of Florida and sponsored by the State Board of Health. In addition, the Operators' Association sponsors short courses in different parts of the state. These regional short courses are held at odd times during the year, between the state short courses, to give operators who can't get to the state course a chance to attend.

From the Floor:—About six or seven years ago one of the Midwest states had an unfortunate experience with a correspondence course. The course was launched with enthusiasm—about 90 people signed up for it—but only about 12 completed it. The course was much too difficult. Those who really needed it didn't get beyond the second lesson; the only ones who completed it were those who didn't need it. The memory of that experience is going to be hard to overcome in promoting an educational program to supplement the voluntary certification program recently inaugurated in that state.

From the Floor:—The so-called "mathematics" actually is nothing more than eighth-grade arithmetic, but to the average operator the word conjures up visions of algebra, calculus, and perhaps logarithms. That alone is sufficient to deter many operators from taking a course. Let's keep courses at the level of the people they are meant for; then they will be successful.

From the Floor:—The International Correspondence Schools have a course that should be given consideration by anyone who is really interested in knowing something in the sewage field brought out in the simplest form. I have had experience with one man who came into the sewage field knowing nothing about it. After taking this course he advanced rapidly as soon as he had the necessary years of experience to meet the standards for certifica-

tion in the State of Ohio. But he had no trouble at all getting a certificate, and within the last year he has secured another position at a much larger plant.

E. J. Beatty, Engineer-Manager, Urbana-Champaign (Ill.) Sanitary District:—Wisconsin had a biennial short course for sewage plant operators. It originally was intended to be a laboratory course for about 20 people, with no repeaters until the entire potential enrollment had been covered. The demand increased, however, to the point where an annual one-week course has been developed to satisfy the needs of both the first-timers and the repeaters. The first-timers take their laboratory work in the afternoons while the repeaters sit in on guided roundtable discussions. Both groups meet together in the mornings to go over technical problems of operation and maintenance.

In Illinois, the annual short course enrollment is limited to 22, the maximum number that can be accommodated in the Sanitary Laboratory at the University of Illinois. The enrollees are picked with the cooperation of the Sanitary Engineering Division of the State Board of Health. Again, those who need the course most are given preference. This short school supplements the one-day sectional and statewide operators' meetings sponsored by the State Sanitary Water Board.

A certain amount of basic mathematics, or arithmetic, is needed in short courses. But there are other things that are, perhaps, even more important. Most of the men taking the courses are brand new in the field. Therefore, the courses serve an important function. I don't believe, however, that they can take the place of the personal contacts that the state regulatory agency representatives should make with the operators in their own plants.

Van P. Enloe, Superintendent of Sewage Treatment, Atlanta, Ga.:—What is believed to have been the pioneer short school in the Southeast recently held its 21st annual meeting. Started jointly by the State Board of Health and Georgia Institute of Technology, the course consists of three days of lectures and laboratory work participated in by engineering consultants, State Board of Health personnel, equipment and material suppliers, etc. It also is followed up with a written examination for both water and sewage plant operators.

The school has been very successful. It is quite encouraging to note that the same type of short school has spread to surrounding states; practically all of them now have a short school of some duration.

As an active participant in short schools for the past 10 or 12 years, I have particularly noticed that several comments in the preceding discussions have borne out experience in those schools. The more practical the short school discussions can be kept, the more valuable they are. From the standpoint of plant operation, for example, it is advantageous to instruct the operators as to exactly what the designing engineer had in mind when he designed the plant; what the Board of Health's plan required when that plant was laid out to suit a certain condition. That type of discussion, of course, spreads to the sewer system, maintenance, etc. But the closer those programs can be kept to the level of the operating forces for which they are designed, the better the service being rendered.

H. S. Smith, Partner, Stanley Engineering Co., Muscatine, Iowa:—It is interesting to note that several previous discussers have indicated that the various short courses, correspondence courses, and other educational offerings have been framed around some certification or licensing base. Regardless of what type of course is offered, the demand for that course must be built up. It has been our experience in Iowa that certification has furnished

a good foundation for that. During the first year of a voluntary certification program administered by the Iowa Sewage Works Association some 70 operators were certified in the higher grades by examination. Also, a great many requests have been received for means of advancement.

Mr. Whitney:—Several State Boards of Health regularly publish bulletins, newsletters, and other aids to operators desiring to know what the regulatory body may expect of them. What is the responsibility of the several State Boards of Health in regard to this method of approach?

W. A. Hasfurther, Sanitary Engineer, State Department of Health, Springfield, Ill.:—The Digester, a quarterly publication of the Division of Sanitary Engineering, Illinois State Department of Public Health, has received considerable favorable comment. It's a lot of work, and the writing is all done by field engineers of the Sanitary Water Board, more or less as an extracurricular activity.

An attempt is made to include more than just items of news interest. News items are included, of course, to give the operator some knowledge of what others are doing in the state. But about two years ago it was decided to add to each issue a section that, when combined with other such sections would eventually constitute an "Operator's Manual." Each section is complete in itself, is about four or five pages long, and is written so that a beginning operator can readily digest it. With this approach, the beginning operator won't just look at it, say it's a little too technical for him, and then throw it away. Under the current publication schedule it will take about three years to get all the sections into print.

The subjects cover everything we can think of. One article was on pumps, another on so-called "mathematics." Most of the operators have expressed great interest in the articles and save them. The Sanitary Water Board encourages this, even to the extent of providing a separate cover so each operator can build up his own manual.

Unless the regulatory agency has a large enough organization to make personal visits and cover all the problems with each operator, the manual approach seems about the only way to give many of them instruction. This is especially true for those in small towns, who probably need it most but who generally have additional duties that prevent them from getting away for the time required by short courses.

TIPS AND QUIPS

Roughing Filter Relieves Overloaded Activated Sludge Plant

Because of rapid growth during the decade from 1940 to 1950, Grove City, Pa., was forced to substantially increase the capacity of its sewage treatment plant. Prior to 1951, the plant provided bar screening, primary settling, sludge digestion, mechanical aeration, final settling, and sludge drying. Capacities were based on an average flow of 0.8 m.g.d. from a population of 7,000. The plant improvements, based on an average flow of 1.5 m.g.d. and a maximum flow of 2.4 m.g.d. from a population of 9,000, consists primarily of a new high-rate roughing filter, 53 ft. in diameter and 6 ft. deep, utilizing 2- by 4-in. slag as the filter medium.

The new filter was designed for a dosing rate of approximately 30 m.g.a.d. Based on 9,000 population and assuming 35 per cent B.O.D. reduction through the primary clarifiers, the filter loading would be about 2 lb.

of B.O.D. per cubic yard. It was expected that about 53 per cent of the applied B.O.D. would be removed through the trickling filter treatment. On this basis, the amount remaining to be handled by the activated sludge process would be only about 37 per cent of the previous loading on these tanks.

In normal operation of the plant, attendants are on duty only during the daytime. Therefore, sampling is done in an 8-hr. period and on peak flows. Hourly composites are made on raw sewage, settled sewage, trickling filter effluent, and final effluent.

In the first half of 1953, removal of applied suspended solids was 62.8 per cent in the primary tanks, 36.8 per cent in the trickling filter, and 85.6 per cent in the aeration tanks, with an overall removal of 96.5 per cent. Of the applied B.O.D., the primary tanks removed 50.1 per cent, trickling filter 58.7 per cent, and aeration 84.3 per cent, with an over-all reduction of 96.6 per cent. The effluent is fully chlorinated during the summer months.

Recirculation is automatically controlled to hold a constant flow through the filter. In the spring of the year *Leptomitus* forms between the filter slag causing some ponding. As the weather warms up, however, the filter gently unloads and returns to normal. *Psychoda* have not created any problem because the bed has been dosed to its extreme circumference by a ¾-in. opening at the end of each distributor arm. This latter arangement has also kept ice from becoming a source of trouble during the winter months.

The foregoing data were supplied by J. N. Hagerich, Superintendent of the

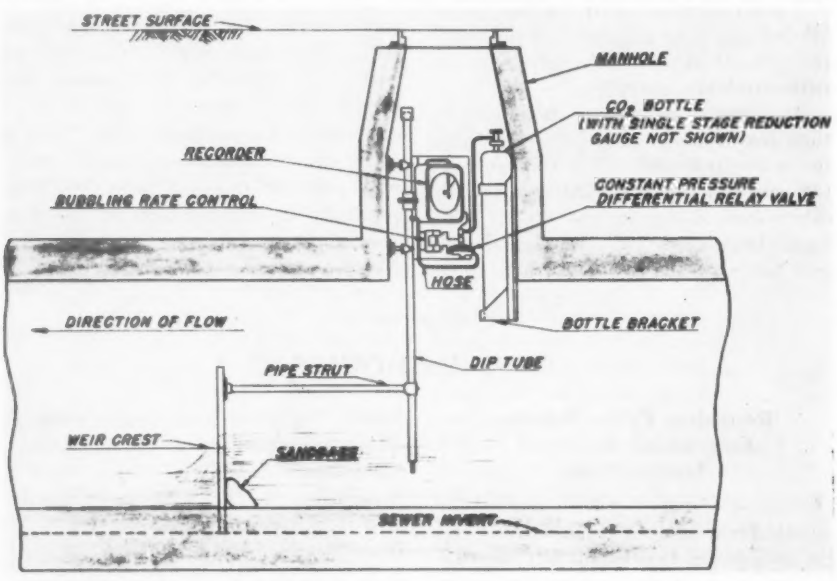

FIGURE 1.—Automatic sewage flow measuring mechanism hung in the upper part of manhole eliminates many hazards connected with usual sewage flow gaging operations under dry-weather conditions. The instrument, designed for Philadelphia by General Industries, Inc., of that city, is based on a recorder measuring the flow of carbon dioxide gas through a dip tube inserted in the impoundment of a weir installed in the sewer. The rate of gas escape is translated into sewage levels by the instrument. After installation of the weir and mechanism, servicing requires only changing the recording chart daily and replacing the CO_2 bottle periodically.

Grove City plant, in a discussion at 1953 Annual Meeting of the Pennsylvania Sewage and Industrial Wastes Association.

Easy Does It

Retrieving of lost tools, parts, or spilled pieces from inaccessible places is made easy by use of powerful small permanent magnets now on the market. One type even has a drilled ⅛-in. standard pipe nipple for fastening rope, wire, or pipe lengths for distant operation, and removable neoprene rings to prevent attraction of the device to a pipe wall.

Such a device is extremely useful for recovering ferrous metallic objects from tanks and similar places without the necessity of dewatering.

Readings on the Fly

The latest wrinkle in remote control, particularly as regards liquid or gas storage conditions, is embodied in a new telemetering instrument developed by the Bristol Co., Waterbury, Conn. The device is operable from any telephone, and even from a radio-telephone equipped truck. Called the "Metaphone," it can be installed at any point in a plant or system.

The device answers the phone when called and gives its reading by a time signal proportional to the pressure involved. Installation and operating costs of the device are said to be considerably less than those of conventional telemetering systems. Also, it is often more useful to a supervisor who doesn't stay in a central control room or pump house, but whose duties make it necessary for him to move about a plant or city.

Just Faded Away

How a former "treatment plant" just faded away under the press of the times was indicated in a paper given at a recent meeting of the Western Section, New York Sewage and Industrial Wastes Association, at Lancaster, N. Y. In describing the new Depew sewage treatment plant project, author Arthur Leupold said:

"In the early days the sewage was treated by passing it through coke beds located on the site of the new sewage treatment plant. During the lean years following World War I, when fuel was hard to get, these coke beds disappeared and Depew's sewage was discharged into the waters of Cayuga Creek."

Would that be "activated" carbon?

Safety Topping

Said to form a thin, tightly-bonded veneer that is slip-proof, wet or dry, and is easily troweled on over concrete, wood, steel, tile, mastic, or terrazo floors, X–L Veneer is a new synthetic heavy-bodied plastic material containing special solvents and abrasive fillers. The manufacturer recommends it for use around machinery and on stairways, ramps, catwalks, aisles, and shower rooms. Available in several colors, the product is said to stand up with remarkable strength, even under steel wheel trucking. Details are available from The Monroe Co., Inc., 10703 Quebec Ave., Cleveland 6, Ohio.

Recording Turbidimeter

Of particular use in monitoring of private water supplies and waste treatment unit discharges, a new recording trubidimeter developed by General Electric's Special Products Section is adjustable over a wide turbidity range (0–25 to 0–10,000 p.p.m., silica scale). With a cycle time of 60 sec., the unit is adapted to continuous-flow process turbidity measurements.

Oil Skimmer

A new device for reclaiming used process oil automatically and constantly skims oil from liquid surfaces regardless of the liquid levels in the collection tanks and chambers. The unit (Figure 2) operates from the liquid level in a chamber through which the waste is flowing, the skimming trough lip being maintained a fraction of an inch below the liquid surface at all times. The recovered oil is delivered to a reclaiming tank by a suction pump and flexible hose.

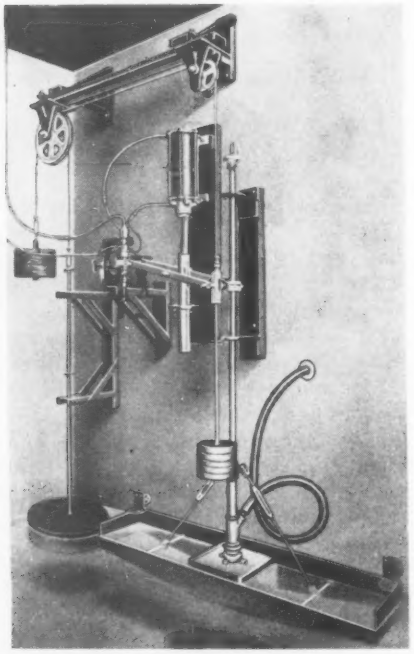

FIGURE 2.—Oil reclaim skimmer operates from collection chamber liquid level. (Photo courtesy Simplex Valve and Meter Co.)

Special Fire Hazards

1. Overheated bearings can be a source of fire. Bearings should be accessible and should be kept free of dust and dirt. It is important that they be properly lubricated in accordance with the manufacturer's instructions.

2. Any moving belt is a potential generator of static electricity and should be grounded. Standard grounding consists of grounding shafts and pulleys and installing metal combs and points connected to a good ground. Because belts are very poor conductors, a belt dressing is used to make it possible to collect and remove the static electricity generated. A safe belt dressing can be made of 18 parts of lampblack and 82 parts of good spar varnish. The dressing must be dried on the belt before the belt is run.

3. Cotton waste and wiping rags impregnated with oil or paint are subject to spontaneous ignition. Oily waste when not in use should be kept in a standard metal waste can, having no soldered joints, a self-closing cover, and raised 3 to 4 inches off the floor by metal legs.

New Terminology

It is only natural that the reporters of the forums at the Federation's annual meetings, being unfamiliar with the technical terminology involved, may occasionally get some queer combinations in transcribing their notes. But in the printed version the reader never gets to see some of the best chuckles, edited out in preparing the copy.

For example, in the Industrial Waste Forum of the Miami meeting, ". . . there was a little *allergy* on the bottom . . ." of a stream recovering from gross pollution in an upstream section. Also, in the Operator's Forum, there was ". . . evidence that there was enough *B.O.* in the final effluent . . ." of a small treatment plant.

Well, maybe the last wasn't a slip at all!

Reviews and Abstracts*

The Drying of Sewage Sludge Under Pressure. By Harold E. Babbitt. Civil Eng. Studies, San. Eng. Series No. 4 (1952).

The release of water from sludge was hoped to be accomplished by heating the sludge under pressure, then suddenly releasing this pressure. The conversion from a liquid to a gaseous state would result "in a release of retained molecules of water, and might serve as an effective method of drying sludge." The sludge is first placed in a pressure "gun," where upon sudden release it is discharged into a "target" receptacle and then to a sand drying bed. Tests showed that heated sludge dries more easily than unheated. However, the "exploded sludge (under pressure) dries no more easily than sludge heated without explosion." The author states that it is evident that the nature of water molecules is not rearranged by sudden transformation from a liquid to a gaseous state in such a manner as to permit the release of "bound" water in sewage sludge. He further concludes, therefore, that the drying of sludge by "explosion" is not a practical or economical procedure.

R. E. Anderson

Sewerage and Drainage of the Greater Vancouver Area, British Columbia. By Charles Gilman Hyde, John Oliver, and A. M. Rawn. 278 pp., planograph (Sept., 1953).

This is a report to the Vancouver and Districts Joint Sewerage and Drainage Board, covering sewerage and storm-water drainage in the Greater Vancouver area. The entire area (about 32 sq. mi.) was divided into three sections, which are treated as independent projects.

The sewerage projects found most economical and satisfactory involve conveying the sewage for final disposal to eight locations, five on the Fraser River, two on Burrard Inlet, and one on the Strait of Georgia. At all but two of these locations, the conditions are such that sewage can be discharged without treatment. At these two locations treatment will be required; in one location, primary, in the other, primary and secondary.

The total population in 1951 was 520,313, with an average use of 139 g.p.c.d. (Imp.). The sewage studies are limited to sanitary flow, with casual reference to industrial wastes, with an average allowance of 95 g.p.c.d. (Imp.) on sanitary sewers and 110 g.p.c.d. (Imp.) on combined sewers.

The report recommends that a joint agency be created to finance, construct, and operate the facilities recommended and to distribute the total annual cost to each of the political entities. The various topics are discussed in detail, with many diagrams and tables, including the subject of disposal in tidal waters.

Langdon Pearse

Controlling Factors in the Choice of Sewage Treatment Process. By W. F. Brown. *Proc. Inst. Civil Eng.*, **2**, 2, Pt. III, 236 (Aug., 1953).

The author discusses briefly the effect on rivers and other bodies of water, of the discharge into them of untreated sewage. The nature of the problem of adequate sewage treatment to prevent pollution of the receiving body of water is examined and the usual criteria (suspended solids content and B.O.D.) of the effluent are stated. Reference is made to the Royal Commission Standards and their application.

The processes now in general use for

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

sewage treatment and sludge treatment and disposal are listed. The factors determining the choice of these processes are as follows:

Primary:

1. Standard required for effluent.
2. Character of sewage to be treated.
3. Size of the system, or quantity of sewage to be treated.
4. Ruling economic factors.

Secondary:

1. Climatic conditions.
2. Conditions relating to site of works.
3. Materials and labor available for construction, operation, and maintenance of the treatment works.

The paper is written largely from a British viewpoint, with occasional reference to American practice, and as such is instructive. The effect of industrial wastes is briefly discussed, although the author suggests such wastes may be largely eliminated under the British laws.

The influence of dietary habits and climate is also touched upon. Storm-water handling is also considered. The limitations of use of treatment processes are pointed out. In the author's opinion, the lower limit of population for the activated sludge process is a population of 50,000. Economic factors must be examined, both on costs of construction, maintenance, and operation, and on areas for sites.

The paper is concluded by several discussions. In closing, the author noted a tendency in practice towards higher standards for sewage effluents, and that where skilled labor is available simplicity might be ignored. LANGDON PEARSE

The Storage, Collection, and Disposal of Domestic Refuse. By J. C. DAWES. *Proc. Inst. Civil Eng.*, **2**, 98 (Apr., 1953).

The work undertaken by local authorities in Great Britain on collecting and disposing of 10,000,000 tons of refuse per year, at a cost of about £16,000,000 sterling, is reviewed.

Storage of refuse at or near dwellings to await collection is considered from a sanitary standpoint, and approved methods are outlined. Portable standard receptacles should be provided and maintained by local authorities under powers conferred by the Public Health Act, 1936, as part of their normal collection equipment. Types and capacities of collection vehicles are referred to and related to local conditions.

Emphasis is placed on the importance of separate collections of organic kitchen waste and its subsequent conversion by heat treatment into a sterile feeding stuff for pigs and poultry.

Five methods of refuse disposal are discussed including controlled tipping (sanitary landfill), separation-incineration, direct incineration, pulverization, and composting. Reference is made to salvage and utilization.

The author estimates the yield of refuse at 1,600 to 1,700 lb. per 1,000 population per day in Great Britain. He also lists the trace elements found therein. He further points out the different meanings of the term "composting." In Holland pulverized refuse at Drente is described as a complete compost, whereas in Great Britain the term is normally applied to a mixture of two or more fermentable substances, such as sewage sludge and domestic refuse. He estimates the annual use of refuse in Great Britain for composting with sewage sludge as small.

Between October, 1939, and July, 1947, he states that 8,896,012 tons of various materials separated from rubbish were sold for £26,247,403.

The discussion comments on certain local situations, and the desirability of special care where refuse is tipped (dumped) on permeable formations overlying chalk from which a water supply is obtained. LANGDON PEARSE

Results of Large-Scale Experiments with High-Rate Activated Sludge Plants and Trickling Filters. By K. WUHRMAN. *Schweis. Zeits. Hydr.*, **15**, 1 (1953).

The aeration tanks contained 38.5 and 77 cu. m. (1,360 and 2,720 cu. ft., respectively), and treated settled sewage from 2,000 to 4,000 people. Volumetric loadings varied from 4.1 to 28.0 cu. m. per cu. m. per day, most frequently between 10 and 22 cu. m. per cu. m. per day. B.O.D. loadings varied from 0.27 to 3.23 kg. per cu. m. per day (16.8 to 202 lb. per 1,000 cu. ft. per day, respectively). Using brush aeration, aeration times lasted usually about 1 hr., applying variations from 28 to 300 min. Variations in brush speeds and depth of brush immersion are given. Returned sludge was not re-

aerated. Most frequent mixed liquor solids concentrations ranged from about 2,000 to 3,300 p.p.m. B.O.D. removals were usually about 80 per cent. Detailed information regarding loadings and removals of $KMnO_4$ O.D., total N, organic N, organic C, and P are also given. Asbestos additions of 1 and 20 p.p.m. to the raw settled sewage had no beneficial effects. The use of the relationship $C_{max} = \frac{W_t}{Q_t}$, in which C = maximum permissible mixed liquor solids concentration, W_t = aeration capacity of tank, and Q_t = oxygen demand of mixed liquor sludge, permits more efficient operating control. Comparison between equivalent power requirements per pound of 5-day B.O.D. of brush and compressed air aeration indicates the former to be twice as efficient. Graphical representation indicates 5-day B.O.D. removals to be a function of initial 5-day B.O.D. concentration and hydraulic loading. When comparing this function with results obtained by others (Okun, Greeley) and the results with the function of Fair and Thomas, it is concluded that C_{max} will yield the most efficient 5-day B.O.D. removals. Sludge build-up is a statistically linear function of B.O.D. loading and decreases with sludge age. The results show no relationship between sludge build-up, B.O.D. loading, and mixed liquor solids concentration. Sludge thickening is recommended rather than sludge return to primary sedimentation.

Artificial aeration was used for the trickling filter experiments. Aerated beds occupied 80 cu. m. (104 cu. yd.) and treated sewage from about 1,000 to 2,000 people at hydraulic loadings usually at 5 or 8 cu. m. per cu. m. day (37.4 to 59.9 g.p.d. per cu. yd.). B.O.D. loadings varied between 0.27 and 1.56 kg. per cu. m. per day (0.455 to 2.63 lb. per cu. yd. per day). Increasing clogging tendencies were experienced with higher loadings in spite of increased air supply. Loadings of 5 cu. m. per cu. m. per day (37.4 g.p.d. per cu. ft.) of sewage above 60 p.p.m. B.O.D. decreased removal efficiencies rapidly.

Activated sludge destroys more organic nitrogen compounds, whereas trickling filters oxidize nitrogen to a greater degree. Both processes transfer 50 to 33 per cent of the total raw sewage nitrogen to the sludge within given loading limits and both lose about 20 to 30 per cent of the initial total N. For the activated sludge process the N deficit may be related to the oxygen supply; for the trickling filter there appears to be a function with loading and/or nitrification. Phosphorus transformations were also studied.

PETER K. MUELLER

Pre-treatment of Industrial Waste Waters with Specific Reference to the Use of Absorption and Extraction Processes. BY H. HILL. *Jour. Inst. San. Eng.*, **52**, 225 (1953).

The concept and practical applications of absorption and extraction are reviewed. The countercurrent extraction of oils from coke and chemical industry wastes is described. In general, heavy oils are used. Benzol is acceptable however, because it is easier to recover for re-use.

The countercurrent washing of industrial sludges is advocated for the recovery of valuable by-products or the greater ease in dewatering. The reduction of free alkali with flue gases is recommended. The advantages and disadvantages of the falling droplet *versus* the rising bubble is analyzed in detail. Removal of color by adsorption on fine particles is described.

R. S. INGOLS

Bacteria in Relation to Water. BY S. W. TAYLOR. *Proc. Inst. Civil Eng.*, **2**, Part III, No. 3, 398 (Dec., 1953).

This is a compilation by a British lawyer, who discusses the problem of bacteria in relation to water. In his opinion, cholera and typhoid are waterborne diseases, whereas paratyphoid is more often associated with infected food. Dysentery and gastro-enteritis, on the other hand, are rarely waterborne, and then are usually due to gross contamination. The spread of leptospiral jaundice and tularemia is caused by the causative organisms being liberated into the water by rats. Catarrhal jaundice and poliomyelitis are caused by viruses recoverable from excreta. Whereas jaundice can arise from contaminated water, poliomyelitis has not been shown to do so.

Historically, his review starts with the work of Robert Koch in 1876 and outlines the nature of bacteria and viruses and pathogenic bacteria. Various epidemics are cited around the world.

Topics covered are early water bacteriology, parasitic bacteria, saprophytic bacteria, with notes on British practice on water analysis, autotrophic bacteria, filamentous bacteria, streptomyces, and molds causing tastes and odors in waters. The importance of the bacteriologist is emphasized in protection of water supply. Some 34 references are cited. A discussion follows by 11 specialists.

Although largely based on British technique, the paper should interest all sanitary engineers. LANGDON PEARSE

Small Sewage Treatment Works for Rural Housing Estates. BY T. G. FAULKNER. *Jour. Inst. San. Eng.*, **52**, 241 (1953).

This article reviews the problem of the type of sewage treatment units best adapted to small housing developments in suburban areas where a city sanitary sewer is not available. The location of the small plant is important so that the odor will not offend nearby residents. For primary treatment, septic tanks require less maintenance, but produce odors; settling tanks must be serviced regularly. The sludge should be buried or carted off to a city treatment plant if possible.

Trickling filters are the best form of secondary treatment except that they liberate the most odor and produce flies. Pumps should be automatic where needed.

Adequate maintenance is essential.

R. S. INGOLS

Further Work on the Sludge Freezing Process. BY A. BRUCE, G. S. CLEMENTS, AND R. A. STEPHENSON. *Surveyor*, **112**, 849 (Dec. 5, 1953).

The data reported in this paper deal primarily with the vacuum filtration of sewage sludge after freezing and thawing. Using a wool filter cloth, it was found that after being used six or eight times, the cloth became clogged with fines, and the filtration time increased from 30 sec. to 15 min. Washing in water restored the cloth to its original condition. Elutriation of the sludge to remove fines did not prevent clogging, but rather resulted in partial deflocculation of the sludge. Reversal of the cloth on successive runs was successful, and 29 successive runs are reported without increase of filtration time.

Other filtering media tested included metal gauzes, cotton twill, and fabrics of certain synthetic fibers. Of the materials examined, fabrics woven of polyvinyl chloride monofilaments proved most satisfactory.

Centrifugal dewatering of the sludge was unsuccessful, in that the separated liquor contained a high content of solids too finely divided for easy removal.

Reference is made to data on the availability (for nitrification) of the nitrogen content of primary sludge, in connection with its agricultural value.

Digestion of activated sludge did not improve its response to freezing, and resulted in loss of 23 to 25 per cent of its nitrogen. It was concluded, therefore, that digestion of activated sludge before freezing offers no advantage. M. C. RAND

Report of the Water Pollution Research Board for 1952. Her Majesty's Stat. Off., London, Eng. 64 pp. (1953).

This twentieth report presents material on the following topics:

Water; some factors affecting the bactericidal action of chlorine (pp. 5–6) enumeration of *Streptococcus faecalis* in polluted water (pp. 7–8); removal of radio-iodine during normal treatment of domestic water supplies (pp. 8–12);

Sewage; biological filtration of sewage (pp. 12–18); mechanical filtration of sewage effluent (p. 19) to improve effluent; further nitrification of sewage works effluent by high-rate biological filtration (pp. 20–21); treatment of domestic sewage from groups of houses (pp. 21–25), with data on septic tanks, followed by percolating filter; factors affecting growth of fungi in percolating filters (pp. 26–28); treatment by biological filtration of sewage containing spent gas liquor (pp. 29–31);

Industrial Waste Waters (pp. 31–40), including alkaline wastes from kiering of waste cotton, using coagulants, or percolating filters, or anaerobic digestion; wastes containing cyanides on percolating filters; treating wash waters containing emulsified oil; ceramic wash waters;

Toxicity of substances to fish (pp. 42–45).

The report closes with a survey of the Thames estuary (pp. 45–59), with interesting factual data on salinity and tons of 5-day B.O.D. received, and suspended solids and bottom deposits. The two

London outfalls were estimated to have discharged 70,000 tons (dry weight) of suspended solids in 1951. From upland waters in 1951, 124,612 tons were received. The production and oxidation of sulfide is also cited, with comment on the condition of estuary water.

The report is excellent and may be obtained for $0.65 from the British Information Services, 30 Rockefeller Plaza, New York 20, N. Y. LANGDON PEARSE

Metropolitan Water, Sewerage, and Drainage Board, Sydney, N. S. W., Australia. 64th Ann. Rep. for Year Ended June 30, 1952. 40 pp. (1953).

This is a very complete report, with financial data and maps of a Board serving Sydney and suburban areas, with an area of 3,993 sq. mi. and a population on June 30, 1952 of 2,000,000 receiving water service, 400,000 sewerage, and 853,900 drainage. Most of the population are located in an area of 526 sq. mi.

The water supply is obtained from a catchment area of 3,388 sq. mi., of which 836 sq. mi. are under the direct control of the Board. The annual rainfall varies from 27 to 79 in. The water consumption varies monthly from 124.0 to 207.4 m.g.d., and an annual average of 155.9 m.g.d., or 79.1 g.p.c.d.

Sydney and its suburbs are served by three major sewer systems, which discharge without treatment to the Pacific Ocean into 30 ft. of water. There are five minor systems, of which three go direct to the ocean and two drain to local treatment works. The sewers have a length of 2,999.8 mi. In 1952, the total expenditure was £6,607,702.

Research is continuing on the deterioration of concrete sewers and the deodorizing of sewer gas by ozone.

LANGDON PEARSE

Detection of Tubercle Bacilli in Sewage from Sanatoria. BY K. WAGENER, E. MISCHTCHERLICH, AND V. REUSS. *Ges. Ing.*, **74**, No. 9–10 (1953).

In these studies, the authors mixed sanatorium sewage with 0.5 per cent Bradosol, a quaternary ammonium compound of negligible activity against tubercle bacilli. After standing for 10 min. and centrifuging for 20 min. at 2,500 r.p.m., the sediment was diluted serially in Koch's saline, and concurrently injected subcutaneously into guinea pigs and plated on Hohn's medium (egg-base medium). Animal inoculation proved a more sensitive method and less subject to saprophytic contamination than plate culture. Four surveys of a sanatorium sewage by these techniques revealed the following numbers of tubercle bacilli per ml.: raw sewage, 10,000 to 100,000 by animal inoculation and 0 to 100 by plate culture, respectively; Imhoff tank effluent, 100 to 10,000 and 0 to 2,000; at outfall in stream, 1,000 and 0 to 200; 30 meters below outfall, 0 to 1,000 and 0 to 100; 250 meters below outfall, 0 to 100 and 0; 30 meters after confluence with larger river (1,750 meters from plant), 0 to 2 and 0.

MARC S. ALBANESE

BOOKS, REPORTS, AND PAMPHLETS

Research Projects in the Pulp and Paper Industry—1952. Amer. Paper and Pulp Assn., 122 East 42nd St., New York 17, N. Y. (1953).

This annual report of the Association's Committee on Coordination of Research lists and briefly describes research projects relating to the paper and pulp industry, including wastes, with the names of the organizations doing the research.

Proceedings of the Second Annual Symposium on Water Conservation and Industrial Development. Eng. Exper. Station Bull. No. 38, Louisiana State Univ., Baton Rouge 3, La. (1953).

Includes the text of papers presented at the symposium, held November 19–20, 1952.

Probability Tables for the Analysis of Extreme-Value Data. National Bureau of Standards. Supt. of Doc., U. S. Govt. Printing Off., Washington, D. C. Price, $0.25 (1953).

These specialized tables in Applied Mathematics Series 22 find use in the statistical approach to such practical problems as the study of floods and droughts, sewage flows, and treatment results.

Book Reviews

Design and Operation of Septic Tanks. World Health Org. Monograph Series No. 18, Columbia Press, New York, N. Y. 122 pp. Price, $1.50 (1953).

This is a collection of some of the papers presented at the Third European Seminar for Sanitary Engineers, held in London October 27–November 1, 1952. The material is presented as a guide to local health departments, sanitary engineers, and others actively engaged in rural and urban sanitation in designing treatment and disposal of domestic sewage from small groups of houses and isolated dwellings.

The basic data and principles given for the design and operation of this type of sewage installation, and especially the observations on maintenance, could serve as a useful guide to designers, operators, and regulatory bodies concerned with this type of unit.

Papers included in the book are as follows:

"Health Considerations Involved in the Treatment and Disposal of Sewage from Isolated Dwellings," by J. A. Scott, Medical Officer of Health, London, England.

"Factors Governing Sewage Treatment in Small Sewage Plants," by F. Meinck, Director, Institute of Water, Soil, and Air Hygiene, Berlin, Germany.

"Principles of Design for Small Domestic Sewage Treatment Works," by F. G. Hill, Adviser on Sewerage and Sewage Disposal, Ministry of Housing and Local Government, and G. L. Ackers, Chief Sanitary Engineer, Ministry of Works, London, England.

"Treatment of Domestic Sewage in Plants Serving Small Groups of Houses," by A. E. J. Pettet and E. E. Jones, Assistant Director and Senior Experimental Officer, respectively, Water Pollution Research Laboratory, Dept. of Scientific and Industrial Research, Great Britain.

"Effect of Treatment of Domestic Sewage in Small Plants on the Counts of Faecal Bacteria: Comparison with the Results of Treatment in Large-Scale Sewage Works," by L. A. Allen and H. M. Smith, Water Pollution Research Laboratory, Dept. of Scientific and Industrial Research, Great Britain.

"Septic Tanks and Other Small Sewage Treatment Works in Switzerland," by Walter Dardel, Consulting Engineer, Aarberg, Berne, Switzerland.

"A Comparative Study of Septic Tanks," by E. LeClerc, I. Beeckmans de West-Meerbeeck, and L. P. Philips, Centre Belge d'Etude et de Documentation des Eaux, Liège, Belgium.

Following a summary of the discussions of the several papers, an appendix presents a detailed description of a sand filter for use in a single structure with a septic tank. A selected bibliography on septic tanks and similar small sewage treatment units contains 170 entries.

H. P. Orland

Handbook of Municipal Drainage (Taschenbuch der Stadtentwässerung). By Karl Imhoff. 15th Edition. 335 pages, 88 illus. R. Oldenbourg, Munich, Germany (1954).

The 15th Edition of Dr. Imhoff's well-known pocket-size handbook brings its coverage up-to-date in all chapters. New features are the design computations for storm-water storage tanks according to Müller-Neuhaus and a design chart for air piping after Lemke and Merkel. The new edition is available in an attractive and serviceable leather cover.

A more complete review of the preceding edition will be found on page 540 of the April 1952 issue of This Journal.

W. H. Wisely

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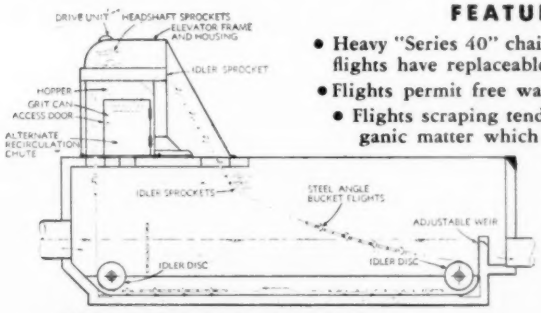

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Proceedings of Member Associations

PACIFIC NORTHWEST SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 19th Annual Meeting of the Pacific Northwest Sewage and Industrial Wastes Association was held November 5–7, 1953, at the Hotel Chinook, Yakima, Wash. Registration for the meeting totaled 223.

Papers presented at the technical sessions included the following:

Symposium on "Utilization of Water Resources—A River Basin View," by William Galbraith, Director, Washington Dept. of Conservation and Development; R. R. Harris, USPHS, Portland, Ore.; Dr. S. R. Benner, Health officer, Yakima City-County Health Dept.; and E. F. Eldridge, Director and Chief Engineer, Washington Pollution Control Commission.

Panel discussion on "Treatment Plant Operation from the Layman's and the Operator's Viewpoints."

Panel discussion on "Treatment Plant Design and Construction."

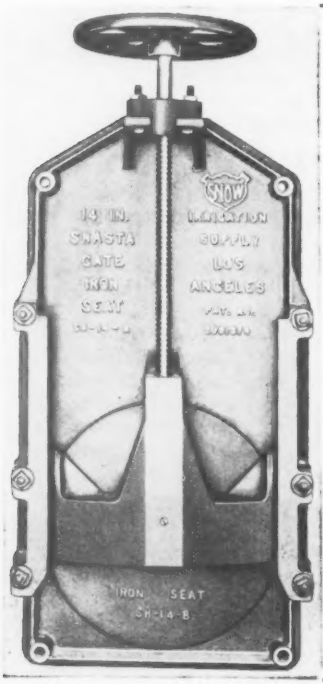
Panel discussion on "Sewer Jointing Materials."

"The Disposal of Radioactive Wastes," by A. L. Biladeau, Sanitary Engineer, U. S. Atomic Energy Commission, Arco, Idaho.

"Reverse Cycle Heating in Sewage Treatment Plants," by George S. Smith, Professor of Electrical Engineering, University of Washington.

"Composting of Municipal Garbage," by C. J. Geraghty, Office of Clyde Kennedy, San Francisco.

(*Continued on page 192a*)



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Vice-President: F. Merryfield, Corvallis, Ore.
Secretary-Treasurer: W. W. Saxton, Olympia, Wash.

WALTER W. SAXTON,
Secretary-Treasurer

NEW YORK SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 26th Annual Meeting of the New York Sewage and Industrial Wastes Association was held at the Belmont Plaza Hotel, New York, N. Y., on January 21–22, 1954. Registration of members and guests totaled 337.

Technical papers presented at the meeting included the following:

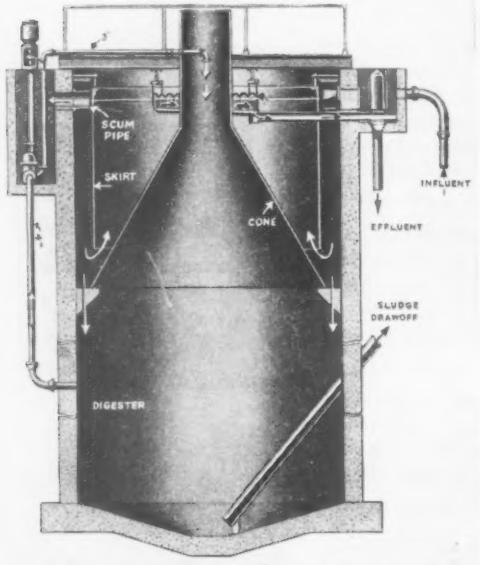
"Flow Measurements in Sewage Works," by Walter H. Brown, Project Engineer, Builders-Providence, Inc., Providence, R. I., and G. E. Symons, Technical Consultant, Larchmont, N. Y.

"Liquid Waste Treatment at Orangeburg Manufacturing Company," by William E. Stanley, Professor of Sanitary Engineering, Massachusetts Institute of Technology, and Robert D. Ellis, Process Engineer, Orangeburg Mfg. Co., Orangeburg, N. Y.

"Progress Report—New York State Water Pollution Control Program," by A. F. Dappert, Executive Secretary, New York State Water Pollution Control Board.

"Disposal of Electroplating Wastes by Oneida, Ltd.," by C. A. Walker, *et al.*, Associate Professor of Chemical Engineering, Yale University.

(*Continued on page 194a*)



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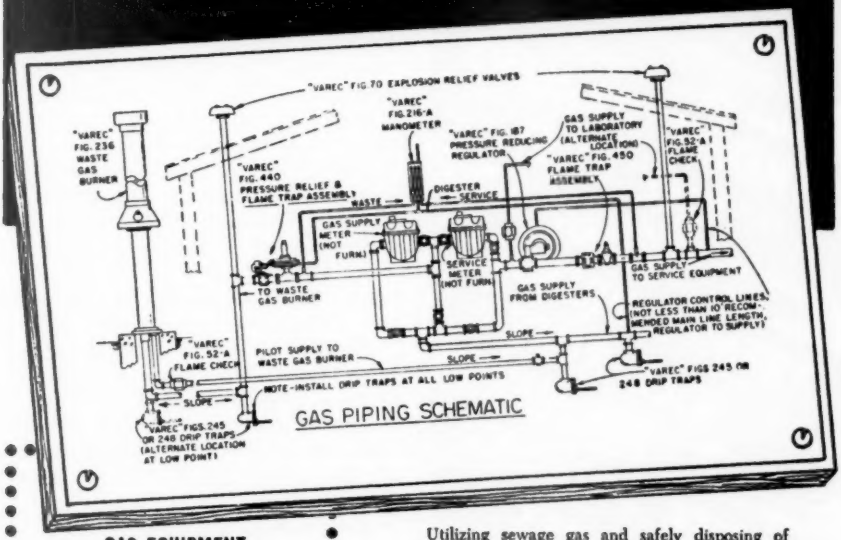
"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATIONS)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES (NOT LESS THAN 10 RECOMMENDED MAIN LINE LENGTH, REGULATOR TO SUPPLY)
SLOPE
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
"VAREC" FIGS 245 OR 248 DRIP TRAPS
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
SLOPE
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

a. **PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 440

b. **FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

c. **FLAME CHECK**
"VAREC" Fig. No. 52A

d. **EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

e. **WASTE GAS BURNER**
"VAREC" Fig. No. 236

f. **DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

g. **MANOMETERS**
"VAREC" Fig. No. 216A

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"A Rational Approach to Industrial Waste Treatment," by L. L. Hedgepeth, American Cyanamid Corp.

"Industrial Wastes along the Niagara Frontier, and Their Effect on the International Boundary Waters," by Hayse H. Black, Sanitary Engineer, USPHS, Cincinnati, Ohio, and Earl Devendorf, Director, Bureau of Environmental Sanitation, New York State Dept. of Health.

Industrial Waste Reduction by Mill Improvement." by R. N. Drummond, Chief Research Chemist, International Paper Co., Glens Falls, N. Y.

"Oil Refinery Waste Treatment," by W. H. Lang, Standard Oil Development Co., Linden, N. J.

"Design and Operation of a Phenol Recovery Plant," by J. C. McCord, Assistant Superintendent, Lackawanna (N. Y.) Plant, Bethlehem Steel Co.

"Sewage Treatment at Port Washington," by C. MacCallum, Consulting Engineer, Port Washington, N. Y.

"Activated Aeration at the Wards Island Plant," by A. H. Chasick, Sanitary Engineer, New York City Dept. of Public Works.

"Relationship of Current Standards for Sanitary Sewers to Present Community Needs," by C. C. Spencer, Director of Environmental Sanitation, Erie County (N. Y.) Health Dept.

The Federation's Arthur Sidney Bedell Award was presented to A. J. Fischer.

At the Business Meeting it was reported that the Executive Committee had reestablished the Association's Rating Awards for operators' reports. Officers elected were as follows:

President: W. L. Edwards, Gowanda.
Vice-President: C. E. Irving Schenectady.
Treasurer: J. C. Brigham, Albany.
Secretary: R. C. Sweeney, White Plains.

R. C. SWEENEY,
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